Joint Technical Programme


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Executive Summary

Clean Sky today epitomises a true Public Private Partnership (PPP). It represents a strategic and successful input to the Europe 2020 objectives: boosting private investments in research and innovation and making the best use of public research funding in a vital and growing sector. Five years into the Programme, the step-change improvement potential targeted, such as up to 30% reduction in CO₂ emissions and (depending on the aircraft segment) 60% reduction in noise footprint, are all within reach. Stakeholder participation is a huge success: first time participation from many SMEs and their success rate in the Calls for Proposals is over twice that of any other FP7 instrument. Industry is increasingly using Clean Sky as the centrepiece of their R&T programmes because of the flexibility of the instrument; and the JU has proven its efficiency as management body.

The aeronautical sector, in particular through Clean Sky 2, will be a critical player in contributing to one of the key Societal Challenge ‘smart, green and integrated transport’ defined in Horizon 2020. The Clean Sky 2 Programme included in the ‘Innovation Investment Package’ will serve society’s needs and strengthen global industry leadership. It will enable cutting edge solutions for further gains in decreasing fuel burn and CO₂ and reducing NOₓ and noise emissions. It will contribute strongly to the renewed ACARE SRIA¹.

Clean Sky 2 will build on the success of Clean Sky and will deliver full-scale in-flight demonstration of novel architectures and configurations. Advanced technology inserted and demonstrated at full systems level will enable step-changes in environmental and economic performance and bring crucial competitiveness benefits to European industry. By jointly pursuing this research on new breakthrough innovations and demonstrating new vehicle configurations in flight, the Programme will provide the proving grounds for concepts that would otherwise be beyond the manageable risk of the private sector. It will give the necessary funding stability to the private sector to develop and introduce game-changing innovations within timeframes that are otherwise unachievable. Compared to the best available aircraft in operation in 2014, up to a 30% reduction in fuel burn and related CO₂ emissions, similar or greater reductions in NOₓ emissions and up to a 75% reduction in noise affected communities will accrue from this focused and programmatic approach. These pace-setting gains will enable the European Aviation Sector to satisfy society’s needs for sustainable, competitive mobility towards 2050. By doing this, Clean Sky 2 will be the key European instrument to speed up technology development, overcome market failure and guarantee a sustainable advancement of aviation. Clean Sky 2 will significantly contribute to the Innovation Union, create high-skilled jobs, increase transport efficiency, sustain economic prosperity and drive environmental improvements in the global air transport system.

The proposed Clean Sky 2 Programme will be jointly funded by the European Commission and the major European aeronautics companies, and involves an EU contribution from the Horizon 2020 Programme budget of €1.8 bn. It will be leveraged by further activities funded at national, regional and private levels leading to a total public and private investment of €4.05 bn, Clean Sky 2 will run for the full duration of Horizon 2020 actions, i.e. from 2014 to 2023. A phased approach will be taken to the start-up of Clean Sky 2 projects and align them closely and adequately with Clean Sky on-going projects (to be completed in the period 2014-2016). It will be endorsed and supported by the leading European aeronautic research organisations and academia. Small and medium-size enterprises and innovative sub-sector leaders will continue to shape promising new supply chains. In so doing, Clean Sky 2 will engage the best talent and resources throughout Europe and over 3,000 highly skilled staff (FTEs) will be consistently employed over a ten year period.

¹ Advisory Council on Aviation Research in Europe, Strategic Research and Innovation Agenda (2012)
PART 1 – A *Clean Sky* For Today’s And Tomorrow’s Challenges

1 Meeting the Challenges set in Horizon 2020

As underlined in the EC Communication of July 2013\(^2\), progress towards the Europe 2020 objective of investing 3% of GDP in R&D has been slow, with particular weaknesses in private investments. The *Clean Sky* PPP has proven effective: delivering innovations by combining efforts from public and private stakeholders. The European Aeronautics sector today accounts for nearly half of the world’s fleet in operation or on order. It is of paramount importance to the EU economy; and it helps in meeting society’s needs by ensuring:

- Safe, reliable and competitive mobility for passengers, goods and public services;
- Minimal impact of aviation on the environment through key innovations;
- Significant contribution to the balance of trade, economic growth and competitiveness;
- Retention and growth of highly skilled jobs, supporting Europe’s *knowledge economy*.

Continued growth in demand for air travel raises new environmental and socio-economic challenges. Research and innovation has been and remains core to EU competitiveness and sustainable value creation. The long-term public-private investment made by the European Union and its Aeronautics Sector has made the industry globally competitive, allowing it to drive the innovation agenda in many areas, including environmental performance. But the new challenges identified in ACARE SRIA highlight the need for more accelerated innovation and for more far-reaching solutions. A continuation of the existing *Clean Sky* JTI will ensure new concepts are fully validated in order to accelerate the market adoption of step-change solutions. A continued PPP through *Clean Sky 2* will deliver major gains within the key pillars defined in H2020:

- *Creating resource efficient transport that respects the environment*. *Clean Sky 2* must *finish the job* of achieving the ACARE SRA goals as set for 2020.
- *Ensuring safe and seamless mobility*. New concepts will allow the air transport system to meet the mobility needs of citizens: more efficient use of local airports, faster connections, and reduced congestion.
- *Building industrial leadership in Europe*. *Clean Sky 2* will help protect and develop highly skilled jobs within European aeronautics and its supply chain, including academia, ROs and SMEs; against a backdrop of significantly increased global competition.

By pursuing joint European research on breakthrough innovations and demonstrating new vehicle configurations in flight, *Clean Sky 2* will position industry to invest in the development and introduction of game-changing innovations in timeframes otherwise unachievable. In doing so, it will significantly contribute to Europe’s *Innovation Union*.

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\(^2\) COM (2013) 494 Final: Public-private partnerships in Horizon 2020: a powerful tool to deliver on innovation and growth in Europe
2 The Rationale for *Clean Sky 2*

The Horizon 2020 period will be decisive for delivering the innovations defining this century’s fleet and its environmental footprint. *Clean Sky 2* results will be applicable to 75% of the world fleet needing replacement\(^3\) up to 2050, and *Clean Sky 2* technology will be able to address aviation emissions totalling over 70% of the worldwide civil air fleet\(^4\).

Mastering the full aeronautics research and innovation chain is a prerequisite to sustaining global competitiveness. In the past 5 years, *Clean Sky* has become the single most important instrument to address large research topics of advanced maturity up to the demonstration of integrated complex systems, in parallel with the ATM R&D in SESAR. The set-up as JTI has proven itself as the most effective way to ensure all relevant European stakeholders (including academia, research organizations and SMEs) cooperate in developing the most promising technologies towards future industrial application. *Clean Sky 2* can further engage and align all the stakeholders in the European value chain, trigger research investments from public and private sector players, and permit the pooling and aligning of required capacities and capabilities from across Europe. This will deliver the innovation and growth needed as well as drive further investment well beyond its own technical scope.

*Clean Sky 2* will be a natural continuation of *Clean Sky*. Close alignment in time and in content between the two will allow enable a seamless transition. Based on the technology readiness level (TRL) demonstrated at the end of *Clean Sky*, several technologies will be ready for potential development and deployment. Others will need to be matured further within a research environment. Some of the most innovative and promising technologies worked on in *Clean Sky* require a higher level of system integration. This next step - demonstrating representative full-scale vehicle architectures - should give the required confidence to market players to invest in break-through innovation. This next step will also allow the *Clean Sky 2* Programme to exploit synergies between *Clean Sky* technologies and those matured outside *Clean Sky* with potential complementary benefits. Innovation from *Clean Sky 2* will drive major advances in the next generation of aircraft by mastering the technologies and the risks, in time to meet the market window to replace the current fleet.

The economic context

On average, 12% of aeronautic sector revenues, representing almost €7 bn per year for civil aeronautics alone, are reinvested in Research and Development (R&D) and support around 20% of aerospace jobs. The industry accounts for approximately 3% of EU workforce, generates roughly €220 bn of the European GDP per year\(^5\), and contributes positively to the EU’s trade balance with over 60% of its products exported\(^6\). Every Euro invested in aeronautics R&D creates an equivalent additional value in the economy every year thereafter.

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\(^3\) Based on the proportion of the short to medium range aircraft in the global that will need to be replaced. Data derived from the Airbus Global market Forecast 2011-2030.


\(^5\) ACARE SRIA for 2020-2050, p. 4.

\(^6\) ACARE SRIA for 2020-2050, p.7; export figure refers to 2009.
Meeting society’s requirements

Aviation is and will remain a vital enabler of our economy and society. Air traffic is forecast to grow by 4% to 5% per year in the next decades leading to a 4-7-fold increase in traffic by 2050\(^7\). This poses major environmental, societal and economic challenges that can only be tackled through an intense and sustained cooperation between public authorities, industry, research organisations, academia and SMEs.

The renewed ACARE SRIA was completed in 2012, with ambitious goals for a sustainable and competitive aviation sector. These include a 75% reduction in \(\text{CO}_2\) emissions, a 90% reduction in \(\text{NO}_x\) and 65% in perceived noise by 2050 compared to 2000 levels, and 4 hour door-to-door journey for 90% of European travellers. These substantial emissions reductions and mobility goals require radically new aircraft technology inserted into new aircraft configurations. Building on the substantial gains made in Clean Sky, Clean Sky 2 aims at meeting the overall high-level goals with respect to energy efficiency and environmental performance shown in the following:

<table>
<thead>
<tr>
<th></th>
<th><strong>Clean Sky 2 as proposed</strong>(^*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{CO}_2) and Fuel Burn</td>
<td>-20% to -30% (2025 / 2035)</td>
</tr>
<tr>
<td>(\text{NO}_x)</td>
<td>-20% to -40% (2025 / 2035)</td>
</tr>
<tr>
<td>Population exposed to noise / Noise footprint impact</td>
<td>Up to -75% (2035)</td>
</tr>
</tbody>
</table>

* Baseline for these figures is best available performance in 2014

These figures represent the additionality of CS2 versus the 2014 Horizon 2020 Start Date and allow the full completion of the original ACARE 2020 goals (with a modest delay).

The overall socio-economic and environmental benefits of Clean Sky 2 will go well beyond the impact of Clean Sky. With increasing demand for air travel the market opportunity is larger and the environmental need is greater than when the original Clean Sky proposal was drafted. The Programme needs to build on the first phase of work but it also needs to be more ambitious in order to:

- Accelerate the progress towards the ACARE SRIA goals for 2020-2050;
- Enable a technological leap in the face of emerging competitors;
- Justify the early replacement of aircraft that have yet to enter service and accelerate the adoption of new technology into the global fleet.

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The Clean Sky 2 economic and environmental benefit

The Programme aims to accelerate the introduction of new technology in the 2025-2035 timeframe. By 2050, 75% of the world’s fleet now in service (or on order) will be replaced by aircraft that can deploy Clean Sky 2 technologies. Based on the same methodology as applied in the Clean Sky economic case in 2007 the market opportunity related to these programmes is estimated at ~€2000 Bn. The direct economic benefit is estimated at ~€350-€400bn and the associated spill-over is of the order of € 400bn. These figures are additive with respect to the Economic Value Added expected from Clean Sky.

As a result of higher growth forecast, the environmental case for continuing the Programme into a second phase is even more compelling with an estimate of the CO₂ saving potential of 4bn tonnes through Clean Sky 2. These 4bn tonnes of the CO₂ to be saved from 2020 to 2050 will be additive to the approximately 3bn tonnes achievable as a consequence of Clean Sky.

The importance of public-private partnership

Clean Sky 2 will focus and allow the coordination of aviation stakeholders’ initiatives and investments at a European scale. It will give the necessary stability and stimulus to the aviation sector stakeholders to introduce game-changing innovations at a scale and in a timeframe otherwise unachievable. Clean Sky 2 will reduce the high commercial risk that is associated with research activity in the aeronautics sector and which is beyond the capacity of private industry. As Public-Private Partnership it will attract strong private investment on the prerequisite that this is complemented with the same amount of public funding.

The spill-over effects of the aeronautical industry

Aeronautical technologies are a proven catalyst for innovation and spill-over into many other sectors⁸. The main reasons are the severe performance, environmental, weight, safety requirements any aeronautical products must comply with, as well as the necessity of a “system” vision and the management of complexity. As a consequence, historically after an aeronautical application, with the contribution of large investments, skills and efforts to meet the severe requirements, a technology is extended to another field allowing it to achieve a competitive advantage and stay on the technology leading edge. Aeronautics has been the first-user promoter of many new technologies or processes which later spread over many other application fields.

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3 Building on Clean Sky: the structure of Clean Sky 2

Clean Sky has demonstrated clear benefits in terms of accelerating technology development. Major developments are being made possible in different systems such as optimized wing designs, new fuselage construction concepts, energy efficient engine architectures, new flight guidance systems and ‘more electric’ on-board systems. These technological advances need to be integrated into complete aircraft to render the next generation of air vehicles more efficient and reduce emissions and noise. In addition, new vehicle configurations will have to be evaluated with flight demonstrators as they will be essential to fulfil the ambitious objectives of renewed ACARE SRIA.

Evidence is mounting that conventional aircraft configurations are approaching intrinsic performance limits, as the integration of the most recent technologies are showing diminishing returns. Therefore, the need today is even greater for industry to develop materially different, substantially more environmentally friendly vehicles to meet market needs, and ensure their efficient integration at the air transport system level. Clean Sky 2 will continue to use the Integrated Technology Demonstrators (ITDs) mechanism when appropriate. Its objective-driven agenda to support real market requirements providing the necessary flexibility is well suited to the needs of the major integrator companies. The new Programme will also focus on reinforcing interactions between demonstrations of improved systems for a better integration into viable full vehicle architectures. The Clean Sky 2 structure will involve demonstrations and simulations of several systems jointly at the full vehicle level through Innovative Aircraft Demonstrator Platforms (IADPs).

A number of key areas will be coordinated across the ITDs and IADPs through Transverse Activities where additional benefit can be brought to the Programme through increased coherence, common tools and methods, and shared know-how in areas of common interest.

As in Clean Sky, a dedicated monitoring function - the Technology Evaluator (TE) will be incorporated in Clean Sky 2.

Innovative Aircraft Demonstrator Platforms (IADPs)

IADPs will aim to carry out proof of aircraft systems, design and functions on fully representative innovative aircraft configurations in an integrated environment and close to real operational conditions. To simulate and test the interaction and impact of the various systems in the different aircraft types, vehicle demonstration platforms are proposed covering passenger aircraft, regional aircraft and rotorcraft. The choice of demonstration platforms is geared to the most promising and appropriate market opportunities to ensure the best and most rapid exploitation of the results of Clean Sky 2. The “integrated approach” that a JTI-based research programme can provide is not feasible using other instruments typical of the former Framework Programmes (e.g., Level 1 / Level 2 projects). The IADP approach can uniquely provide:

- Focused, long-term commitment of project partners;
- An “integrated” approach to R&T activities and interactions among the partners;
- Stable, long-term funding and budget allocation;
- Flexibility to address topics through open Call for Proposals;
- Feedback to ITDs on experiences, challenges and barriers to be resolved longer term;
- A long-term view to innovation and appropriate solutions for a wide range of issues.
Integrated Technology Demonstrators (ITDs)

In addition to the complex vehicle configurations, Integrated Technology Demonstrators (ITDs) will accommodate the main relevant technology streams for all air vehicle applications. They allow the maturing of verified and validated technologies from their basic levels to the integration of entire functional systems. They have the ability to cover quite a wide range of technology readiness levels. Each of the three ISDs orientates a set of technology developments that will be brought from component level maturity up to the demonstration of overall performance at systems level to support the innovative flight vehicle configurations:

- Airframe comprising topics affecting the global vehicle-level design;
- Engines for all propulsion and power plant solutions;
- Systems comprising on all board systems, equipment and the interaction with the ATS

Transverse Activities

Some activities can be relevant for various IADPs and ITDs. These “Transverse Activities” do not form a separate IADP or ITD, but are an integral part of the other IADPs and ITDs. A dedicated budget will be reserved inside the concerned IADPs and ITDs to perform these activities. Leaders will be nominated for each Transverse Activity. So far, two Transverse Activities are agreed for Clean Sky 2:

- ECO-Design: life cycle optimization of the technologies, components and vehicles;
- Small Air Transport (SAT): airframe, engines and systems technologies for small aircraft, extracting synergies where feasible with the other segments.

The Technology Evaluator (TE)

A Technology and Impact Evaluation infrastructure is an essential element within the Clean Sky PPP and will be continued. Impact Assessments such as at Airport and ATS level currently focused on noise and emissions will be expanded where relevant for the evaluation of the Programme’s delivered value. Where applicable they can include the other impacts, such as the mobility or increased productivity benefits of Clean Sky 2 concepts. The TE will also perform evaluations on aircraft “Mission Level” to assess innovative long term aircraft configurations.
4 Membership and participation in the Clean Sky 2 Programme

Membership of the Clean Sky 2 involved in the CS2 Programme will be comprised of:

- The European Commission representing the Union and ensuring EU public policy;
- Leaders committed to achieve the full research and demonstrator activity of the Programme
- Core-Partners with a substantial long-term commitment towards the Programme

Core-Partners will be chosen through open and competitive calls, guaranteeing a transparent selection of the best membership and strategic participation. In addition, Partners will be invited to participate in specific topics and projects in the scope of a well-defined limited commitment. These Partners will be selected as a result of open Calls for Proposals (CFP).

With 60% of funding open to competition, Clean Sky 2 will foster wide participation where SMEs, research organisations and academia interact directly with key industry stakeholders. Up to half of this 60% will be awarded to Core Partners who will join the JU as Members, ensuring the long term Programme stability needed to meet the relevant ACARE Goals. Clean Sky 2 is expected to involve at least 800 participants from the European aeronautics players and also new entrants in this field.

From Clean Sky to Clean Sky 2: the principles of transition

A phased approach will be taken to the start-up of Clean Sky 2 projects. In very broad terms, in the first 4 years Clean Sky developed and demonstrated technologies up to TRL4-5. From there on a selection of the most promising and mutually additive technologies are now being subsequently taken to TRL6 system level demonstration, by 2016. In some specific cases, Clean Sky ITDs will bring a small number of high-potential - but less mature - technologies up to TRL4 through a focused effort during the 2014-17 period. These will not be validated at TRL6 within Clean Sky but can be good candidates for continuation in Clean Sky 2.

Clean Sky 2 IADPs will use results from Clean Sky as a start towards integration studies in the 2014-2017 timeframe. Clean Sky or Clean Sky 2 ITD level outputs will form key inputs into the configuration and content of demonstrations.

The activities within Clean Sky will be pursued until completion according to plan. Then the technology integration may be launched in a Clean Sky 2 IADP or, if the maturity at this point is deemed not sufficient for integration, the technology development will be continued as part of the relevant ITD. An IADP may start in Clean Sky 2 while some of the integrated technologies have not yet passed the final validation tests. The architecture and configuration trade-off studies can be launched in an IADP as soon as the specifications and interfaces of the components and subsystems to be integrated can be frozen. Consequently, the activities within Clean Sky ITDs can be completed according to their own work plan at the latest in 2016 while new activities are launched within Clean Sky 2 ITDs and IADPs according to a staggered schedule starting in 2014, the start of Horizon 2020, at the earliest.
Part 2 – *Clean Sky 2* Programme Scope and Structure

### 5 Clean Sky 2 – Introduction to the Programme Technical Content

#### 5.1 Structure of the *Clean Sky 2* Programme

The *Clean Sky 2* Programme consists of four different elements, as shown in the picture below:

- Three Innovative Aircraft Demonstrator Platforms (IADPs) for Large Passenger Aircraft (LPA), Regional Aircraft and Fast Rotorcraft, operating demonstrators at vehicle level,
- Three Integrated Technology Demonstrators (ITDs), looking at Airframe, Engines and Systems, using demonstrators at system level,
- The Technology Evaluator (TE), assessing the environmental and societal impact of the technologies developed in the IADPs and ITDs,
- Two Transverse Activities (Eco-Design, Small Air Transport (SAT)), integrating the knowledge of different ITDs and IADPs for specific applications.

![Figure 5.1 - Structure of the *Clean Sky 2* Programme](image)

The proposed total funding available as per define by the Clean Sky 2 Regulation is 1,755 M€ of which 39 M€ correspond to the contribution towards the Joint Undertaking running costs, leading to a funding available for the *Clean Sky 2* technical activities of 1,716 M€.
Out of this funding, 1% (17.2 M€) is intended for the Technology Evaluator, not being part of the IADPs and ITDs technical programme. This finally leads to a net funding available for the IADPs and ITDs of 1,698.8 M€.

In contrast to the Technology Evaluator, the Eco-Design and Small Air Transport Transverse Activities are technically and budgetary part of the IADPs and ITDs, as can be seen in Figure 5.1. While the Eco-Design activities (39 M€) are proportionally distributed over all IADPs and ITDs, the Small Air Transport funding is split between Airframe (30 M€), Engines (18 M€) and Systems ITD (20 M€).

The agreed funding available is reflected in the table below:

<table>
<thead>
<tr>
<th>IADP / ITD</th>
<th>Funding Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Passenger Aircraft IADP</td>
<td>521.0 M€</td>
</tr>
<tr>
<td>Regional Aircraft IADP</td>
<td>104.2 M€</td>
</tr>
<tr>
<td>Fast Rotorcraft IADP</td>
<td>190.2 M€</td>
</tr>
<tr>
<td>Airframe ITD</td>
<td>347.1 M€</td>
</tr>
<tr>
<td>Engines ITD</td>
<td>289.8 M€</td>
</tr>
<tr>
<td>Systems ITD</td>
<td>246.5 M€</td>
</tr>
<tr>
<td><strong>Total IADPs &amp; ITDs</strong></td>
<td><strong>1,698.8 M€</strong></td>
</tr>
<tr>
<td>Technology Evaluator</td>
<td>17.2 M€</td>
</tr>
<tr>
<td><strong>Total Technical Activities</strong></td>
<td><strong>1,716.0 M€</strong></td>
</tr>
<tr>
<td>JU Running Costs</td>
<td>39.0 M€</td>
</tr>
<tr>
<td><strong>Total Clean Sky 2</strong></td>
<td><strong>1,755.0 M€</strong></td>
</tr>
</tbody>
</table>
5.2 Key Activities of the ITDs, IADPs and Transverse Activities

5.2.1 Large Passenger Aircraft IADP

The Large Passenger Aircraft IADP approach builds on the positive experience in Smart Fixed Wing Aircraft (SFWA) in Clean Sky. The Airbus A340-300 based BLADE laminar wing flight test demonstrator, the Airbus A340-600 based CROR demo engine flying test-bed and two different Dassault Falcon-based low speed and load control flight tests under preparation will provide unique contributions towards maturing technologies for application in next generations of aircraft.

For Clean Sky 2, the Large Passenger Aircraft goal is high-TRL demonstration of the best candidates to accomplish the combined key ACARE goals with respect to the environment, fulfilling future market needs and improving the competitiveness of future products. The setup of the main programme objectives is to further push the value of technologies tackled in Clean Sky, e.g. the integration of CROR propulsion systems, and to add the validation of additional key technologies like hybrid laminarity for the wing, horizontal and vertical tail plane as well as an all-new next generation fuselage cabin and cockpit-navigation suite validated at integrated level with large scale demonstrators in operational conditions.

The focus is on large-scale demonstration of technologies integrated at aircraft level in three distinct ‘Platforms’:

- **Platform 1 “Advanced Engine and Aircraft Configurations”** will provide the environment to explore and validate the integration of the most fuel efficient propulsion concept for next generation short and medium range aircraft, the CROR engine. Large scale demonstration will include extensive flight testing with a full size demo engine mounted to the Airbus A340-600 test aircraft, and a full size rear end structural ground demonstrator. Two demonstrators are planned to mature the concept of “hybrid laminarity” targeting for a substantial aerodynamic drag reduction for next generation long range aircraft. A further demonstration is planned for a comprehensive exploration of the concept of dynamically scaled flight testing. The target is to examine the representativeness of dynamically scaled testing for technology demonstration with highly unconventional aircraft configuration, that means flight test demonstration that are virtually impossible with modified “standard” test aircraft.

- **Platform 2 “Innovative Physical Integration Cabin – System – Structure”** is targeting to develop, mature, and demonstrate an entirely new, advanced fuselage structural concept developed in full alignment towards a next generation cabin-cargo architecture, including all relevant principle aircraft systems. To be able to account for the substantially different requirements of the test programs, the large scale demonstration will be based on three individual major demonstrators. A lower centre section fuselage and one “typical” fuselage stretching from aft of the center section to the pressure bulkhead will be developed, manufactured and tested with focus on loads and fatigue aspects. A further “typical” fuselage demonstrator will be dedicated to integrate and test a next generation large passenger aircraft cabin and cargo. A number of smaller test rigs and component demonstrators will also be part of the Programme in the preparatory phase. Targeting to accomplish technology readiness level 6, manufacturing and assembly concepts for the next generation integrated fuselage-cabin-cargo approach will be developed and demonstrated in a “future factory” work package.
Platform 3 “Next Generation Aircraft Systems, Cockpit and Avionics” has a clear focus to develop and demonstrate a next generation cockpit and navigation suite. Based on the results of a number of research programmes which are currently ongoing or to be started shortly, platform 3 shall provide the Programme to integrate and validate all functions and features which are emerging from individual developments into a disruptive new concept in a major demonstrator suite. With the core of platform 3 being a highly representative ground demonstrator of the future cockpit for large passenger aircraft, selected features and functions will be brought to flight test demonstration. The scope of platform 3 will cover the development of a new next generation cockpit concept, a rethinking towards a “function” based cockpit to operate the aircraft, specifically including all navigation and flight guidance features and function required to incorporate next generation flight and trajectory management capabilities.

5.2.2 Regional Aircraft IADP

Regional aircraft are a key element of Clean Sky through a dedicated ITD - Green Regional Aircraft (GRA), providing essential building blocks towards an air transport system that respects the environment, ensures safe and seamless mobility, and builds industrial leadership in Europe. In Clean Sky 2 the Regional Aircraft IADP will bring the integration of technologies to a further level of complexity and maturity than currently pursued in Clean Sky. The goal is to integrate and validate, at aircraft level, advanced technologies for regional aircraft so as to drastically de-risk their integration on future products. The demonstration objectives of the Regional IADP are much more complex, comprehensive and challenging than those of the current Clean Sky GRA project, which was forced to work within budget and time constraints. Taking into account the outcomes of GRA and considering the high level objectives derived from recent market analysis performed by the Leaders, the strategy is to integrate and validate, at aircraft level, advanced technologies for regional aircraft so as to drastically de-risk their integration on the following future products:

- Near/mid term (in-service from 2022-25 on): Regional Aircraft with underwing mounted turboprop engines,
- Long term (enter in service beyond 2035): Breakthrough Regional Aircraft Configurations, e.g. a/c with rear fuselage mounted turboprop engines

The following demonstration programmes for regional aircraft a/c are now foreseen:

- 2 Flying Test-beds (to minimize the technical and programme risks) using modified existing regional TP a/c with underwing mounted engines, for demonstration campaigns of: air vehicle configuration technologies; wing structure with integrated systems and propulsion integration; flight dynamics, aerodynamic and loads alleviation; advanced flight controls and general systems, and avionics functionalities.
- 5 Large Integrated Ground Demonstrators: full-scale wing, full-scale cockpit; full-scale fuselage and cabin; all including their associated systems; flight simulator; iron bird. In addition a Nacelle ground demonstrator will be done in the Airframe ITD.

Full-scale demonstrations, with acceptable risk and complexity but still providing the requested integration, are essential to allow the insertion of breakthrough technologies on future regional aircraft products, near/mid term and long term as above stated. The individual Technology Developments are arranged along with 8 “Waves” and several individual roadmaps. These technology waves will be developed through roadmaps defined to satisfy the high-level requirements of the future Highly-Efficient Next Generation Regional Aircraft, the configuration of
which will be developed at conceptual level in a dedicated work package. To increase synergies and cross fertilization across the different ITDs and IADPs some of the above technological roadmaps will be shared with the “streams” of the Airframe ITD and with the developments of sub-systems and systems planned inside Systems and Engine ITD. The Demonstration Programme will be divided into technologically compatible and “scope close” demonstrations sub-programmes:

- **FTB1 - Innovative Wing and Flight Controls (Regional IADP):** Integration and flight testing of technologies suitable to regional aircraft applications for a new generation wing and advanced flight control systems. Innovative wing related systems and wing structural solutions will also be incorporated where feasible. Aerodynamic enhancements and LC&A features will be considered to complement FTB2, such as: outboard wing featuring laminar airfoils for skin friction reduction; high A/R by means of adaptive/innovative winglets.

- **FTB2 - Flight Demonstration of a high efficient and low noise Wing with Integrated Structural and related Systems solution, including power plant aspects (Regional IADP):** A new wing will be designed, manufactured and equipped with new structural solutions strongly integrated with advanced low power and high efficient systems such as ice protection, fuel, flight control, engine systems, LE and winglets morphing.

- **Full-scale innovative fuselage and passenger cabin (Regional IADP):** Integration and on-ground testing of a full scale innovative fuselage and passenger cabin including all the on board systems and advanced solutions for increasing passenger comfort and safety. The fuselage will be a full scale demonstration of technologies for composite material, structures and manufacturing aimed to weight and cost reduction and to minimize the environmental impact through eco-design and energy consumption optimization all along the life-cycle (towards a zero-impact).

- **Flight Simulator (Regional IADP):** Starting from the Clean Sky GRA Flight Simulator, an advanced Flight Simulator will be set up and used to demonstrate new cockpit interaction concepts as well as advanced avionics functionalities.

- **Iron Bird (Regional IADP):** Virtual and Physical “Iron Birds” will also be an important part of the Regional A/C Ground Demonstration Programme. These will be used to integrate, optimize and validate the systems modification of the Flying Test Bed and the results of their simulations and ground testing will be essential to achieve the permit-to-fly.

- **Ground Demonstration of the wing (Airframe ITD),** including the airframe and the related systems.

- **Ground Demonstration of the Cockpit (Airframe ITD),** including the structure and related system.

- **Nacelle ground demonstration (Airframe ITD).**

### 5.2.3 Fast Rotorcraft IADP

The Fast Rotorcraft IADP consists of two separate demonstrators, the Tiltrotor demonstrator and the Compound Rotorcraft demonstrator.

The Fast Rotorcraft IADP consists of two concurrent demonstrators, the Tiltrotor demonstrator and the Compound Rotorcraft demonstrator along with transversal activities relevant for both fast rotorcraft concepts.

- **Tranversal activities:**

These activities cover the methodology for technology evaluation of fast rotorcraft demonstrations and the Eco-Design concept implementation, along with the programme management activities for the Fast Rotorcraft IADP.
Concerning the methodology for technology evaluation, the activities will allow defining SMART objectives and criteria adapted to the fast rotorcraft missions in line with the general TE approach for Clean Sky 2. In addition, the tools used in GRC1-GRC7 will be adapted and further developed in order to enable the assessment of conceptual rotorcraft models corresponding to the new configurations to be demonstrated.

Concerning Eco-Design concept implementation. The activities will allow coordinating approaches and work plans in the two demonstration projects regarding the greening of rotorcraft production processes and ensuring complementarity of case studies. The general Life Cycle Assessment approach will be coordinated with the participants of the Eco-Design TA.

- **The Tiltrotor demonstrator NextGenCTR:**

NextGenCTR will be dedicated to design, build and fly an innovative next generation civil tiltrotor technology demonstrator, the configuration of which will go beyond current architectures of this type of aircraft. NextGenCTR’s demonstration activities will aim at validating its architecture; technologies/systems and operational concepts. Demonstration activities will show significant improvement with respect to current Tiltrotors’ state-of-the-art. The project will also allow to develop substantial R&T activities to increase the know-how about a new platform like a tiltrotor (not yet certified as a civil aircraft), and to generate a research and innovation volume of activities above a certain critical mass (not available today for Tiltrotors within EU), somewhat comparable to that of well proven conventional helicopter platforms.

NextGenCTR will continue and further develop what has been initiated in Clean Sky, and launch new activities specific to Clean Sky 2 and NextGenCTR project. In the area of CO₂ emissions reduction, NextGenCTR will continue/develop engine installation and flight trajectories optimisation (this is now done by analytical models and with scaled model tests, whereas Clean Sky 2 will validate it at full scale), while specific Clean Sky 2 new activities on drag reduction of the prop-rotor and airframe fuselage and wing will be necessary (due to a new generation of prop-rotor, modified fuselage-wing architecture). This latter Clean Sky 2 specific topic will also be related to operation costs reduction to address competitiveness of the architecture and solutions adopted. The new prop-rotor will require substantial research (aero-acoustics, by modelling/by tests) to reduce noise emissions (then validated at full scale); in the current Clean Sky, noise reduction is mainly addressed through trajectories optimisation (that will anyhow continue in Clean Sky 2 and will be linked to SESAR concepts where necessary). Clean Sky 2 transversal subjects will cover new material (e.g. thermoplastics, surface treatments, less hydraulics and more electrical systems) validating them at full scale and in real operational conditions, and sustain the development of the Technology Evaluator for the case of the tiltrotor (today not widely considered).

Parameters needs to be defined to show Clean Sky 2 achieved progress according to a specific tiltrotor roadmap (a direct comparison with conventional helicopters architecture seems not appropriate as the two configurations must be regarded as substantially different types of rotary-wing platforms). Today, certified Tiltrotors are not available in the civil sector (while only one product is available in the military); hence, a database from which baseline information for the current state-of-the-art can be extracted is not available. Therefore, ‘key performance parameters’ (KPP) will be introduced to show NextGenCTR’s progress with respect to reference data taken as baseline (mainly referring to technologies which have been tested or conceptually designed in the period 2005-2012). Objectives will be defined considering tiltrotor specificities and in line with the main pillars of Horizon 2020 towards a Smart, Green and Integrated Transport and Clean Sky 2 which addresses environmental compatibility (Greening Objectives), competitiveness (Industrial Leadership) and mobility. Considerable attention to the project’s impact on EU Economy and Jobs creation will be considered, to confirm and further sustain a
steady growth of the sector with regard to revenues, workforce productivity, high rate of new employment (in particular of higher educated personnel) and R&D expenditure.

- **The Compound Rotorcraft demonstrator:**

The LifeRCraft project aims at demonstrating that the compound rotorcraft configuration implementing and combining cutting-edge technologies as from the current Clean Sky Programme opens up new mobility roles that neither conventional helicopters nor fixed wing aircraft can currently cover in a way sustainable for both the operators and the industry. The project will ultimately substantiate the possibility to combine in an advanced rotorcraft the following capabilities: payload capacity, agility in vertical flight including capability to land on unprepared surfaces nearby obstacles and to load/unload rescue personnel and victims while hovering, long range, high cruise speed, low fuel consumption and gas emission, low community noise impact, and productivity for operators.

A large scale flightworthy demonstrator embodying the new European compound rotorcraft architecture will be designed, integrated and flight tested. This demonstrator will allow reaching the Technology Readiness Level 6 at whole aircraft level in 2020. The project is based on:

- identified mobility requirements and environmental protection objectives;
- lessons learnt from earlier experimentation with the low scale exploratory aircraft X3;
- technology progress achieved for rotorcraft subsystems on one side through participation to Clean Sky projects and other research activities at EU or local level;

The individual technologies from the first Clean Sky Programme (Green Rotorcraft ITD, Smart Green Operations ITD, Eco-Design ITD) that will be further matured and integrated in this LifeRCraft demonstration concerns:

- New rotor blade concepts aiming rotor blade concepts aiming at improved lifting efficiency and minimum noise esp. through 3D-optimised shape; the methodology and computational tools required for such optimization;
- Airframe drag reduction through shape modifications and interference suppression;
- Engine intake loss reduction and muffling;
- Innovative electrical systems e.g. brushless generators, high voltage network, efficient energy storage and conversion, electrical actuation designed for weight and on-board energy savings;
- Eco-Design approach, with substitution of harmful materials by new ones and green production techniques, demonstrated for specific rotorcraft components;
- Helicopter fly-neighbourly demonstration based on new flight guidance function and specific approach procedures in both VFR conditions and ATM, SESAR-compliant;

This LifeCraft project essentially consists of the following main activities and deliveries:

- **Airframe structure and landing system:** Advanced composite or hybrid metallic/composite construction, featuring low weight and aerodynamic efficiency;
- **Lifting rotor and propellers:** Low drag hub, pylon and nacelles, 3D-optimized blade design;
- **Drive train and power plant:** New drive train architecture and engine installation optimised for the LifeRCraft configuration;
- **On board energy, cabin and mission systems:** Implementation of the more electrical rotorcraft concept to minimise power off-takes from the engines and drive system;
### Clean Sky 2 Joint Technology Initiative in Aeronautics

- **Flight control, guidance and navigation**: Smart flight control exploiting additional control degrees of freedom inherent to LifeRCraft configuration for best fuel economy and quieter flight;
- **LifeCraft Demonstrator overall design, integration and testing**: All coordination and cross cutting activities relevant to the whole vehicle delivering a full range of ground & flight test results and final conclusion.

#### 5.2.4 Airframe ITD

Aircraft level objectives on greening, industrial leadership and enhanced mobility, and the fulfilment of future market requirements and contribution to growth cannot be met without strong progress on the airframe. Within *Clean Sky* a more efficient wing with natural laminarity, optimised control surfaces and control systems, will have been demonstrated. Also novel engine integration strategies will have been derived and tested, and innovative fuselage structures investigated.

Altogether strong progress towards the 2020 targets will have been obtained when *Clean Sky* is completed (estimated at 75% of the relevant part of the initial ACARE goals, applicable to aircraft with an EIS from 2020/22). However further progress is required on the most complex and challenging requirement on new vehicle integration to fully meet the 2020 objective, and to progress towards the 2050 goals. To make this possible, different directions are proposed:

All of these directions of progress will be enabled throughout the foreseen execution of 9 major Technology Streams:

- **Innovative Aircraft Architecture**, to investigate some radical transformations of the aircraft architecture. The aim of this Technology Stream is to demonstrate the viability of some most promising advanced aircraft concepts (identifying the key potential showstoppers & exploring relevant solutions, elaborating candidate concepts) and assessing their potentialities.
- **Advanced Laminarity** as a key technological path to further progress on drag reduction, to be applied to major drag contributors: nacelle and wing; This Technology Stream aims to increase the Nacelle and Wing Efficiencies by the mean of Extended Laminarity technologies.
- **High Speed Airframe**, to focus on the fuselage & wing step changes enabling better aircraft performances and quality of the delivered mobility service, with reduced fuel consumption and no compromise on overall aircraft capabilities (such as low speed abilities & versatility).
- **Novel Control**, to introduce innovative control systems & strategies to gain in overall aircraft efficiency. The new challenges that could bring step change gains do not more lay in the optimisation of the flight control system component performing its duty of controlling the flight, but to open the perspective to the flight control system as a system contributing to the global architecture optimization. It could contribute to sizing requirements alleviations, thanks to a smart control of the flight dynamics.
- **Novel Travel Experience**, to investigate new cabins including layout and passenger oriented equipment and systems.

The cabin interiors progress is indeed on the path of all societal challenges of the future transport system:

- As a key enabler of product differentiation,
- As having an immediate & direct physical impact on the traveller,
- As having a great potential in terms of weight saving & eco-compliance.
Next Generation Optimized Wing Boxes, leading to progress on the aero-efficiency and the ground testing of innovative wing structures;

The challenge is to develop & demonstrate new wing concepts (including architecture) that will bring significant performance improvements (in drag & weight) while withstanding affordability & environmental stringent constraints withstand.

Optimized High Lift Configurations, to progress on the aero-efficiency of wing, engine mounting & nacelle integration for aircraft who needs to serve small, local airports thanks to excellent field performances.

Advanced Integrated Structures, to optimize the integration of systems in the airframe along with the validation of important structural advances and develop and to make progress on the production efficiency and manufacturing of structures.

Advanced Fuselage to introduce innovation in fuselage shapes and structures, including cockpit & cabins.

New concepts of fuselage are to be introduced to support the future aircrafts and rotorcrafts. More global aero structural optimizations can lead to further improvements on drag & weight in the context of a growing cost & environmental pressure, including emergence of new competitors.

Due to the large scope of technologies undertaken by the Airframe ITD, addressing the full range of aeronautical portfolio (Large passenger Aircraft, Regional Aircraft, Rotorcraft, Business Jet and Small transport Aircraft) and the diversity of technology paths and application objectives, the above technological developments and demonstrations are structured around 2 major Activity Lines, allowing to better focus the integrated demonstrations on a consistent core set of user requirements, and, when appropriate, better serve the respective IADPs:

Activity Line 1: Demonstration of airframe technologies focused towards High Performance & Energy Efficiency (HPE);

Activity Line 2: Demonstration of airframe technologies focused toward High Versatility and Cost Efficiency (HVE).

5.2.5 Engines ITD

In 2007 the European engine industry leaders committed to build and test five engine ground demonstrators covering all the civil market. The goals were to validate to TRL 6 a 15% reduction in CO₂ compared to 2000 baseline, a 60% reduction in NOₓ and a 6dB noise reduction. This is roughly 75% of the ACARE objectives. Following the worst economic downturn in living memory and the consequent changes to market assumptions Clean Sky’s SAGE has adjusted its content to ensure these goals remain achievable. Apart from the consequent delay to the open rotor programme which means that TRL6 is not possible by 2016, the bulk of SAGE objectives remain on track. An open rotor ground demonstrator will run and confirm the CO₂ objective, a lean burn combustion ground demonstrator will run to confirm the NOₓ objective and a GTF will run to confirm the CO₂ improvements and noise advantage of such a configuration. An advanced turbo-shaft engine has already run to ensure the environmental goals extend across the whole market while SAGE 3 has run for the first time to validate the cost and weight advantages of an advanced dressings configuration. Events have shown that the original plans for the open rotor from both Airbus and the engine manufacturers were too ambitious and require further work to confirm both the advantages and credibility of this novel concept.
For *Clean Sky 2*, Safran, MTU and Rolls-Royce have secured corporate commitment to build on the success of SAGE to validate more radical engine architectures to a position where their market acceptability is not determined by technology readiness. The platforms or demonstrators of these engines architectures are summarised below:

- **Open Rotor Flight Test, 2014-2021**: A 2nd version of a Geared Open Rotor demonstrator carrying on *Clean Sky* SAGE 2 achievements and aimed to validate TRL 6 will be tested on ground and then on the Airbus A340 flying test bed (see IADP LPA Programme). From initial SAGE 2 demonstrator some engine modifications aimed to various improvements, control system update, and engine/aircraft integration activities will be necessary.

- **Ultra High Propulsive Efficiency (UHPE) demonstrator addressing Short / Medium Range aircraft market, 2014-2021**: Design, development and ground test of a propulsion system demonstrator to validate the low pressure modules and nacelle technology bricks necessary to enable an Ultra High By-pass Ratio engine (e.g. advanced low pressure fan, innovative nacelle modules, gearbox, pitch change mechanism if any, high speed power turbine). This ground demonstrator will be built around an existing high pressure core.

- **Business aviation / Short range regional Turboprop Demonstrator, 2014-2019**: Design, development and ground testing of a new turboprop engine demonstrator in the 1800-2000 shp class. Base line core of ARDIDEN3 will be improved specifically for turboprop application (compressor up-date, combustion chamber, power turbine) and then integrated with innovative gear box, new air inlet and innovative propeller.

- **Advanced Geared Engine Configuration (HPC and LPT technology demonstration), 2015-2020**: Design, development and ground testing of a new demonstrator to validate key enablers to reduce CO₂ emissions and noise as well as engine weight. Key elements are: improvement of efficiencies, reduction of parasitic energy flows, innovative lightweight and temperature resistant materials, low pressure turbine and exhaust noises reduction.

- **VHBR Large Turbofan demonstrator, 2014-2019**: Design, development, build, ground test and flight test of an engine to demonstrate key technologies at a scale suitable for large engines. An existing engine will provide the core gas generator used for the demonstrator. Key technologies included in this demonstrator will be: integrated low pressure system for a high power very-high bypass ratio engine (fan, compressor, gearbox, LP turbine, VAN), Engine core optimisation and integration, and optimised control systems.

- **Very High Bypass Ratio (VHBR) Middle of Market Turbofan technology, 2014-2018**: Development and demonstration of technologies in each area to deliver validated powerplant systems matured for implementation in full engine systems. Research and demonstration will require the following: behaviour of fans at low speeds and fan pressure ratios and structural technology, aerodynamic and structural design of low pressure turbines for high speed operation, Systems Integration of novel accessory and power gearboxes, optimised power plant integration, Compressor efficiency, and control & electrical power system technology developments

- **The Small Aero-Engine Demonstration** projects related to SAT [Small air Transport] will focus on small fixed-wing aircraft in the general aviation domain, and their power-plant solutions spanning from piston/diesel engines to small turboprop engines. As the demonstration project on business aviation and short-range regional turboprop aircraft (see above) will demonstrate the reliability and efficiency gains in small turbine engines, this area in the Engines ITD will focus on light weight and fuel efficient diesel engines (including the potential exploitation of the 300 kW helicopter engine launched through a CfP under the current *Clean Sky*); and potential hybrid engine architectures (piston/electric engine). In addition (within the overall SAT project
scope), the development and use of low-noise, highly efficient propellers (aimed at hybrid engine, small turbines, diesel engines) will be undertaken.

5.2.6 Systems ITD

While systems and equipment account for a small part of the aircraft weight and environmental footprint, they play a central role in aircraft operation, flight optimisation, and air transport safety at different levels:

- Direct contributions to environmental objectives: optimised green trajectories, electrical taxiing, more electrical aircraft approach, and have a direct impact on CO₂ emissions, fuel consumption, perceived noise, air quality, weight gain.
- Enablers for other innovations: for example, bleedless power generation, actuators, are necessary steps for the implementation of innovative engines or new aircraft configurations.
- Enablers for air transport system optimisation: many of the major improvements identified in SESAR, NextGen and Clean Sky for greening, improved mobility or ATS efficiency can only be reached through the development and the integration of on-board systems such as data link, advanced weather systems, trajectory negotiation, and flight management predictive capabilities.
- Smart answers to market demands: systems and equipment have to increase their intrinsic performance to meet new aircraft needs without a corresponding increase in weight and volume: kW/kg, flux/dm³ are key indicators of systems innovation.

In Clean Sky, the Systems for Green Operations ITD has developed solutions for more efficient aircraft operation. Further maturation and demonstration as well as new developments are needed to accommodate the needs of the next generations of aircraft. In addition, the systemic improvements initiated by SESAR and NextGen will call for new functions and capabilities for environmental or performance objectives, but also for flight optimisation in all conditions, flight safety, crew awareness and efficiency, better maintenance, reduced cost of operations and higher efficiency. Finally, framework improvements will be needed to allow for more efficient, faster and easier-to-certify development and implementation of features and functions. The Systems ITD in Clean Sky 2 will address these challenges through the following actions:

- Work on specific topics and technologies to design and develop individual equipment and systems and demonstrate them in local test benches and integrated demonstrators (up to TRL 5). The main technological domains to be addressed are cockpit environment and mission management, computing platform and networks, innovative wing systems (WIPS, sensors, and actuators), landing gears and electrical systems. Other contributive activities are foreseen and will be carried on by core partners, research centers, etc. The outcome of these developments will be demonstrated systems ready to be customized and integrated in larger settings. An important part of this work will be to identify potential synergies between future aircraft at an early stage to reduce duplication.
- Customisation, integration and maturation of these individual systems and equipment in IADPs demonstrators. This will enable full integrated demonstrations in IADPs and assessment of benefits in representative conditions.
- Transverse actions will also be defined to mature processes and technologies with potential impact on all systems, either during development or operational use. Examples of these transverse actions can be
development framework and tools, simulation, incremental certification, integrated maintenance, eco-design etc.

5.2.7 Technology Evaluator

A Technology and Impact Evaluation project organization and infrastructure was and remains an essential element within the Clean Sky PPP, and will be continued. Impact assessments evaluating the performance potential of the Clean Sky 2 technologies both at vehicle level and at relevant aggregate levels such as at Airport and ATS level, and currently focused on noise and emissions, will be retained. Where appropriate and agreed jointly within the JU Membership they may be expanded to include other relevant environmental or societal impacts, such as mobility benefits or increased productivity.

The analysis of single or logically grouped core technologies on system / vehicle level will be embedded within the IADPs and ITDs, with the TE taking an integrative and ‘synthetic’ approach focusing on the relevance of the Clean Sky 2 output on the Aviation Sector and simulating Air Transport System Impacts.

Therefore, the core aircraft performance characteristics (at the so-called ‘mission level’) will be reported by the IADPs, with clear assigned responsibilities, resource and project tasks embedded in each IADP. Reporting the mission level aircraft capability will reside under the responsibility of the leading company. The IADPs will provide verification and validation of the performance modelling, so as to certify validity of performance predictions. Impact Assessment will be the responsibility of the TE / Impact Evaluator and will focus on aggregate impacts.

For those Clean Sky 2 ITDs technologies not feeding into an IADP aircraft model, the TE will build up its own Mission Level assessment capability, also to assess innovative long term aircraft configurations. Thus, an aircraft-level synthesis of these results via ‘concept aircrafts’ is possible and the respective ITD results can be shown at aircraft level and evaluated within the Airport and Air Transport System alongside the IADP results.

Finally, the progress of each demonstration platform (ITDs and IADPs) will be monitored against the defined environmental and socio-economic benefits and targets via an efficient and effective interfacing between the TE and the ITDs and IADPs. For this, dedicated work packages in the TE (WP2) as well as in the ITDs and IADPs are intended.

In summary, the Technology Evaluator consists of three major tasks:

- Progress Monitoring of Clean Sky 2 achievements vs. defined environmental and societal objectives;
- Evaluation at Mission Level by integrating particular ITD outputs into TE concept aircraft / rotorcraft models;
- Impact Assessments at Airport and ATS Level using IADPs and TEs concept aircraft / rotorcraft models.

Major European Research Institutes and other qualified academic and research participants will be selected on a ‘best athlete approach’ for the TE and will ensure its independent approach, and endorse the analysis on behalf of the CSJU Governing Board. The JU Executive Director will continue to be the Chairman of the TE governing body.
5.2.8 Eco-Design Transverse Activity

Correction: Eco-Design will aim for a roadmap of excellence, to provide high (European) individuality in quality and eco-compliance in the aeronautics vehicles\(^9\), in their whole product life. Eco-Design is reshaped from the former two domain concepts – “Airframe” and “Systems” – into interfaced sub-activity areas that are more open and entrepreneurial:

These areas are as follows:

- The Eco-Design AnalySis (EDAS) activity for next concept (full) REcycle and commensurate Eco-Design Life. All pillars of life value\(^{11}\) are addressed, beyond the conventional “cradle to grave” philosophy, to stimulate better RE-Use options and new, best know-how service options, embracing all the supply chain and OEM actors. EDAS is a knowledge & responsibility empowerment, addressing more widened stakeholder suitability. It shall open up a new supplier/SME interaction basis, and will serve better to grasp full *ground pollution*\(^{10}\) issues and catalyse more clean and efficient processes for improved economic and societal return. Eco-Design principles should be owned by all new programmes and contributors to them. The analysis shall program Eco-Design as enthusiasm value partner for user benefit analyses of the IADP/ITD (acceptance and repeatability, ergonomics and flair, competitive edge value, ecological and economic asset improvement).

- The Vehicle Ecological Economic Synergy (VEES) activity, that is driven from Materials, Processes, Resources (MPR) innovations, secondly from the assimilation of cooperative modules from the ITD/IADP demonstrators with an adaptive Eco Hybrid Platform (EHP), which is totally “LCA+” (Life Cycle Analysis-plus) design driven and an open platform on the level of complete vehicles. This is networked with clustered REcycle for REuse ground facility realisations. LCA+ is used as a receiving-end methodology from the developing Design for Environment (DfE) vision. The Eco-Design work units inside the sub-activities provide a practical footing, always relating to the *Eco-Design Life and REcycle*-theme reference tracked by the transversal coordination. Eco-Design ensures a collective vision of these themes on-board the various ITD/IADP technology streams.

“Eco Architectures”, as one example, covers the main eco-footprint impact on the vehicle from systems performance and indirect energy, water etc. consumption. Close co-operation for these outputs from the major physical benches (electrical, consumer heat output, etc.) will be incorporated. ITD/IADP advanced optimisation methodologies, special physical frame architecture concepts such as next Thermal Frame Benches, Fluid Management Benches etc. will help new *interface trade-offs research*, that fortifies the straight-to-the-point ecolonomics in energy, water/air footprints results.

In the work units’ concept, ECOTech units of clear universal issues (e.g. on corrosion, surface treatments, fire, contamination etc.) will be implemented. Eco-Design will upkeep a sophisticated MPR-Database suitable for aeronautics from the initial *Clean Sky* achievement, offer technical workshops for exchange on LCA, the discourse on DfE, REACH, RoHS, evolving European Standards impacts (indirect water consumption etc.), on concerns such as primary energy demand in production with cost knock-on.

\(^{9}\) Includes also Engine and Systems, and regardless of aircraft, rotorcraft frame definition.

\(^{10}\) Global Warming Potential of substances equated to CO\(_2\)-impact, negative potentials on health and bio diversity, depletion of resources, primary energy demand.
A deeper Eco-Design Statements (ES) concept will ensure the best developed Eco-Design recommendation guidelines from these collaborative sub-activity areas. Stakeholder balanced consultation and user benefit analyses in the so-called *economic harmonisation* process will be exercised on different micro-economic tiers with industrialization scoping to produce well backed socio-economic derivative data; this includes quality labour growth impacts or remedial volumes to tackle and suppress any ground pollution sensitivities. The closure on its material flow and logistics’ output is given through close co-operation with TE in the ITD/IADP top level aggregate delivery.

Eco-Design delivery focuses on quality, eco-compliance and processes whereas the ITD/IADP are front lining the TRL-maturity in the technology streams with component application identity. Together, this will raise the technology strengths in the *Clean Sky 2* Programme.

Eco-Design will deliver success by:

- demonstrating Eco-Design interaction through the ITD/IADP (through shared components contributing to process optimality and eco-compliance up to a/c level),
- bringing all the ITD/IADPs really on board, for instance for the Eco Statements (ES) having consistent and validated process improvements for the technology take-up into big impact technology pathways,
- generating master scientific approaches to match eco-quality and -compliance to high technology readiness promoted through the ITD/IADP,
- creating user enthusiasm value feed-back through Eco-Design principles
- firmly reducing down-cycling, no-future technology down-selection and withdrawal menaces.
- MPR database enhancing EU competitiveness dimension.

Key Eco-Design & REcycle themes:

Identification and Life Information Strategy (not a copy of SHM), MPR, manufacture & production, services to component and system (MRO, Finances/IT Know-How, limited life and extended life integration, inside-outside gate synergy processes), Integration/field-assembly-disassembly-separation, RE-Use, End of Life, Alternative Sectoral Applications, Use Phase (TE feed-back, vehicle utilization closure; eco-values).

### 5.2.9 Small Air Transport (SAT) Transverse Activity

The SAT Initiative proposed in *Clean Sky 2* represents the R&T interests of European manufacturers of small aircraft used for passenger transport (up to 19 passengers) and for cargo transport, belonging to EASA’s CS-23 regulatory base. This includes more than 40 industrial companies (many of which SMEs) accompanied by dozens of research centres and universities. The New Member States industries feature strongly in this market sector. The community covers the full supply chain, i.e. aircraft integrators, engine and systems manufacturers and research organizations.

The approach builds on accomplished or running FP6/FP7 projects. Key areas of societal benefit that will be addressed are:

- Multimodality and passenger choice
- More safe and more efficient small aircraft operation
- Lower environmental impact (noise, fuel, energy)
Revitalization of the European small aircraft industry

To date, most key technologies for the future small aircraft have reached an intermediate level of maturity (TRL3-4). They need further research and experimental demonstration to reach a maturity level of TRL5 or TRL6. The aircraft and systems manufacturers involved in SAT propose to develop, validate and integrate key technologies on dedicated ground demonstrators and flying aircraft demonstrators at an ITD level up to TRL6. The activity will be performed within the Clean Sky 2 ITDs for Airframe, Engines and Systems; with strong co-ordinating and transversally integrating leadership from within a major WP in Airframe ITD.
5.3 Summary of Major Demonstrators and Technology Developments

The table below shows a summary of the major demonstrators and technology developments planned in Clean Sky 2. The supporting research activities not directly embedded into a demonstrator, as well as the management costs, are listed separately. The funding required for the running costs of the Joint Undertaking as well as for the Technology Evaluator are taken into account in the appropriation of the Total Clean Sky 2 EC funding through a dedicated budget calculated in accordance with the proposed CS2 Statutes, as described in Chapter 5.1. For the Eco-Design and Small Air Transport Transverse Activities the funding is embedded within the IADPs and ITDs funding amounts.

<table>
<thead>
<tr>
<th>IADP / ITD</th>
<th>Technology Areas</th>
<th>Demonstrator / Technology Stream</th>
<th>Technologies</th>
<th>Reference Chapter</th>
<th>Complete by</th>
<th>ROM EC funding (in M€)</th>
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<td>Large Passenger Aircraft</td>
<td>Advanced Engine Design &amp; Integration for Large Passenger Aircraft</td>
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<td>Advanced engine integration driven fuselage ground demonstrator</td>
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<td>Advanced Laminar Flow Rig Reduction for Large Passenger Aircraft</td>
<td>HLFC large-scale specimen demonstrator in flight operation</td>
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<td>Next generation lower centre-fuselage structural demonstrator</td>
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<td>IADP / ITD</td>
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<td>Demonstrator / Technology Stream</td>
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<td>Aircraft Systems,</td>
<td>LPA-03-1 Enhanced Flight</td>
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<td>Avionics</td>
<td>LPA-03-2 Innovative enabling</td>
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<td>LPA-03-4 Enhanced Cockpit</td>
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<td>LPA-03-5 Disruptive Cockpit</td>
<td>Demonstration of new cockpit concept: - new crew resource paradigm - integrated cockpit design - functional organisation and architecture - technology enablers (functions, equipments)</td>
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Total: 518
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<th>IADP / ITD</th>
<th>Technology Areas</th>
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<th>Reference Chapter</th>
<th>Complete by</th>
<th>ROM EC funding (in M€)</th>
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<tbody>
<tr>
<td>Regional Aircraft</td>
<td>Highly Efficient Low Noise Wing Design for Regional Aircraft</td>
<td>Air Vehicle Technologies – Flying Test Bed#1 (FTB1)</td>
<td>Low noise and high efficient HLD, NLF, Active LC&amp;A, Innovative wing structure and systems</td>
<td>7.5.3 (I)</td>
<td>2021</td>
<td>22</td>
</tr>
</tbody>
</table>
| Regional Aircraft      | Innovative Passenger Cabin Design & Manufacturing for Regional Aircraft | Full scale innovative Fuselage and passenger Cabin                   | – Advanced High-toughness materials  
– Highly integrated structural concepts  
– SHM for damage detection and condition based maintenance  
– Advanced low-cost manufacturing  
– Highly automated assembly  
– Human centered cabin design  
– All electric/smart Systems integration | 7.5.2 (III)       | 2021        | 31                     |
|                        | Flight Simulator                                                      | New cockpit interaction concepts, advanced avionics functionalities  
(including pilot workload reduction) , MTM (green functions in a global environment)                                                                                                      | 7.5.3 (III)       | 2020        | 6                      |
|                        | Iron Bird                                                             | Innovative systems integration, Next generation flight control systems (H/W and pilot in the loop)                                                                                           | 7.5.3 (IV)        | 2020        | 12                     |
### Regional Aircraft

<table>
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<tr>
<th>Technology Areas</th>
<th>Demonstrator / Technology Stream</th>
<th>Technologies</th>
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</thead>
</table>
| Innovative Future Turboprop Technologies for Regional Aircraft | High Lift Advanced Turboprop – Flying Test Bed#2 (FTB2) | – Active Wing  
– Adaptive Aerodynamics, including Morphing Winglets  
– Wing related Systems integration  
– Advanced CFRP Wing structures  
– Optimized Powerplant integration | 7.5.3 (V)  
7.5.2 | 2017 - 2020 | 23 |
| Regional Aircraft | Linked to all the above Regional Aircraft Demonstrators | Other research activities and management:  
– R-IADP Management (WP 0)  
– Technologies Development & Demonstrations Results Assessment (WP4), including interfaces with TE and Eco-Design transverse activity | 7.4.2  
7.5.4 | 2022 | 5 |

**Total:** 104
### IADP / ITD

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<tr>
<th>Technology Areas</th>
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<th>ROM EC funding (in M€)</th>
</tr>
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<tbody>
<tr>
<td><strong>Fast Rotorcraft: Joint/Transverse activities</strong></td>
<td>Technology Evaluation &amp; Eco Transversal Technologies</td>
<td>D1: Mock-up of major airframe sections and rotor D2: Tie-down helicopter (TDH) D3: NextGenCTR flight demonstrator (ground &amp; flight)</td>
<td>Transverse activities relevant to both FRC demonstrators and management (WP0)</td>
<td>8.5.1</td>
<td>12</td>
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<tr>
<td><strong>Fast Rotorcraft: Tiltrotor</strong></td>
<td>Advanced Tilt Rotor Aerodynamics and Flight Physics Design</td>
<td>D6: NextGenCTR’s fuselage assembly</td>
<td>• System design and integration • Structural and dynamics modelling and analysis software • Aerodynamics/aeroacoustics modelling and analysis • Wind tunnel testing</td>
<td>8.4 (WP1.2)</td>
<td>2018/2019</td>
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</tbody>
</table>

*2015 Clean Sky 2 Joint Technical Programme (V5) – Proprietary Information subject to Confidentiality Agreements*
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<th>IADP / ITD</th>
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</thead>
</table>
|           |                  | D7: NextGenCTR’s wing assembly   | – Aerodynamics modelling and analysis  
– Structure modelling, analysis, testing  
– Advanced composite, metallic materials  
– Complex system design modelling and analysis  
– Design-to cost criteria  
– Design-to weight criteria | 8.4 (WP1.4) | 2018/2019 | 12 |
|           |                  | D8: Engine-airframe physical integration  
D9: Fuel system components | – Aerodynamics modelling and analysis  
– Advanced system modelling, simulation and integration  
– Testing techniques | 8.4 (WP1.5) | 2018/2019 | 9 |
| Fast Rotorcraft: Tiltrotor | Advanced Tilt Rotor Energy Management System Architectures | D5: NextGenCTR’s drive system components and assembly | – Advanced materials for low environmental impact  
– Design-to cost criteria  
– Design-to weight criteria  
– Safe operation for “no-oil” emergency | 8.4 (WP1.3) | 2018/2019 | 10 |
|           |                  | D10: intelligent electrical power system and ancillary/ auxiliary components  
D11: Flight control & actuation systems and components | – High-speed brushless generators  
– Solid statepower conversion and switching units  
– Advanced energy management architectures  
– Smart actuation systems  
– Advanced sensors and inceptors | 8.4 (WP1.6) | 2018/2019 | 22 |
<p>| Fast Rotorcraft: Tiltrotor | Technology Evaluation &amp; Eco Transversal Technologies | Other research activities and management (including support to TE Impact Evaluator): | 8.4 (WP1.0 + WP1.7) | 2024 | 3 |
| Fast Rotorcraft: Tiltrotor |                  | Total: | 89 |</p>
<table>
<thead>
<tr>
<th>IADP / ITD</th>
<th>Technology Areas</th>
<th>Demonstrator / Technology Stream</th>
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<th>Complete by</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Fast Rotorcraft: Compound R/C</td>
<td>Innovative Compound Rotorcraft Design</td>
<td>Airframe structure &amp; landing system &lt;br&gt;NB: Wing and tail addressed in Airframe ITD dedicated WPs (1.8, 1.11)</td>
<td>Advanced composite or hybrid metallic/composite structure using latest design and production techniques e.g. topological optimization, fibre/tape placement, out of autoclave curing, targeting very low weight and accommodating required cabin volume with low drag shape and wide access door for versatile usage (pax, SAR, EMS); Specific landing system architecture &amp; kinematics suited for compound R/C configuration, using composite materials for weight reduction, electrically actuated. Environment-friendly materials and production techniques</td>
<td>8.7.11 &lt;br&gt;8.7.12</td>
<td>2020</td>
<td>17</td>
</tr>
<tr>
<td>Fast Rotorcraft: Compound R/C</td>
<td>Innovative Compound Rotorcraft Power Plant Design</td>
<td>Lifting Rotor &amp; Propellers</td>
<td>Integrated design of hub cap, blades sleeves, pylon fairings, optimized for drag reduction; Rotor blade design for combined hover-high speed flight envelope and variable RPM; Propeller design optimized for best dual function trade-off (yaw control, propulsion); All optimized for best mission performance and noise reduction with provision for icing protection capability, based on extensive use of state-of-art CFD and coupled CFD-CSD tools.</td>
<td>8.7.13 &lt;br&gt;8.7.14</td>
<td>2020</td>
<td>6</td>
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<tr>
<td>IADP / ITD</td>
<td>Technology Areas</td>
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<tr>
<td></td>
<td>Drive train &amp; Power Plant</td>
<td>Engine installation optimized for power loss reduction, low weight, low aerodynamic drag, all weather operation; New mechanical architecture for high speed shafts, Main Gear Box input gears, lateral shafts, Propeller Gear boxes, optimized for high torque capability, long life, low weight. REACh-compliant materials and surface treatments.</td>
<td>8.7.15 8.7.16</td>
<td>2020</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Fast Rotorcraft: Compound R/C</td>
<td>Innovative Compound Rotorcraft Avionics, Utilities &amp; Flight Control Systems</td>
<td>On board energy, cabin &amp; mission systems</td>
<td>Implementation of innovative electrical generation &amp; conversion, high voltage network, optimized for efficiency &amp; low weight; advanced cabin insulation &amp; ECS for acoustic and thermal comfort.</td>
<td>8.7.17 8.7.20</td>
<td>2020</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Flight Control, Guidance &amp; Navigation Systems</td>
<td>Smart flight control exploiting additional control degrees of freedom for best vehicle aerodynamic efficiency and for noise impact reduction.</td>
<td>8.7.18 8.7.19 8.7.21</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast Rotorcraft: Compound R/C</td>
<td>LifeRCraft Flight Demonstrator</td>
<td>LifeRCraft Flight Demonstrator</td>
<td>Integration of all technologies on a unique large scale flight demonstrator, success &amp; compliance with objectives validated through extensive range of ground &amp; flight tests.</td>
<td>8.7.10 8.7.22</td>
<td>2020</td>
<td>21</td>
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<tr>
<td>Fast Rotorcraft: Compound R/C</td>
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<tr>
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<td>Fast Rotorcraft: Compound R/C</td>
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<td>Total: 89</td>
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<tr>
<td></td>
<td></td>
<td>Advanced Laminarity</td>
<td>Laminar nacelle, flow control for engine pylons, NLF, advanced CFD, aerodynamic flow control, manufacturing and assembly technologies, accurate transition modelling, optimum shape design, HLF</td>
<td>9.6.2</td>
<td>TRL 6: 2017 for further IADP testing</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High Speed Airframe</td>
<td>Composites (D&amp;M), steering, wing / fuselage integration, Gust Load Alleviation, flutter control, innovative shape and structure for fuselage and cockpit, eco-efficient materials and processes</td>
<td>9.6.3</td>
<td>TRL 4/5: 2020</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Novel Control</td>
<td>Gust Load Alleviation, flutter control, morphing, smart mechanism, mechanical structure, actuation, control algorithm</td>
<td>9.6.4</td>
<td>TRL 5/6: 2019</td>
<td>12</td>
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<tr>
<td></td>
<td></td>
<td>Novel Travel Experience</td>
<td>Ergonomics, cabin noise reduction, seats &amp; crash protection, eco-friendly materials, human centered design, light weight furniture, smart galley</td>
<td>9.6.5</td>
<td>TRL 6: 2020</td>
<td>11</td>
</tr>
<tr>
<td>Airframe</td>
<td>High Versatility and Cost Efficiency</td>
<td>Next Generation Optimized Wing Box</td>
<td>Composite (D&amp;M), out of autoclave process, modern thermoplastics, wing aero-shape optimisation, morphing, advanced coatings, flow and load control, low cost and high rate production</td>
<td>9.7.1</td>
<td>TRL 5: 2018 for further IADP testing TRL 6: 2020</td>
<td>31</td>
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<tr>
<td>IADP / ITD</td>
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<td>Demonstrator / Technology Stream</td>
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<td>Optimized High Lift Configurations</td>
<td>Tprop integration on high wing, optimised nacelle shape, high integration of Tprop nacelle (composite/metallic), high lift wing devices, active load protection</td>
<td>9.7.2</td>
<td>TRL 5: 2018 for further IADP testing</td>
<td>23</td>
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<tr>
<td></td>
<td></td>
<td>Advanced Integrated Structures</td>
<td>Highly integrated cockpit structure (composite metallic, multifunctional materials), all electrical wing, electrical anti-ice for nacelle, integration of systems in nacelle, materials and manufacturing process, affordable small aircraft manufacturing, small a/c systems integration</td>
<td>9.7.3</td>
<td>TRL 5: 2018 for further IADP testing TRL 6: 2020</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advanced Fuselage</td>
<td>Rotor-less tail for fast r/c (CFD optimisation, flow control, structural design), pressurised fuselage for fast r/c, more affordable composite fuselage, affordable and low weight cabin</td>
<td>9.7.4</td>
<td>TRL 5: 2018 for further IADP testing</td>
<td>68</td>
</tr>
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Airframe Management and interfacing Business jet, LPA, SAT, Rotorcraft and Regional a/c OAD and configuration n/a 9.5 2020 10

Airframe Total: 347
## IADP / ITD Technology Areas

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<tr>
<th>IADP / ITD</th>
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<th>Demonstrator / Technology Stream</th>
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<th>Reference Chapter</th>
<th>Complete by</th>
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<tbody>
<tr>
<td>Engines</td>
<td>Innovative Open Rotor Engine Configurations</td>
<td>Open Rotor Flight Test</td>
<td>Ground test and flight test of a Geared Open Rotor demonstrator: - Studies and design of engine and control system update and modifications for final flight test - Manufacturing, procurement and engine assembly for ground test checking before flight</td>
<td>10.5.1 10.6.1 10.7.1</td>
<td>(2019)</td>
<td>6 Included in LPA IADP figures</td>
</tr>
<tr>
<td>Engines</td>
<td>Innovative High Bypass Ratio Engine Configurations I : UHPE Concept for Short/Medium Range aircraft (Safran)</td>
<td>UHPE demonstrator</td>
<td>Design, development and ground tests of a propulsion system demonstrator for an Ultra High By-pass Ratio engine: validation of the low pressure modules and nacelle technology</td>
<td>10.5.2 10.6.2 10.7.2</td>
<td>(2022)</td>
<td>77</td>
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<tr>
<td>Engines</td>
<td>Business Aviation/Short Range Regional Turboprop Demonstrator</td>
<td>Business aviation/short range regional Turboprop Demonstrator</td>
<td>Design, development and ground testing of a new turboprop engine demonstrator for business aviation and short range regional application</td>
<td>10.5.3 10.6.3 10.7.3</td>
<td>(2019)</td>
<td>22 TRL5/6</td>
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<tr>
<td>Engines</td>
<td>Advanced Geared Engine Configuration</td>
<td>Advanced Geared Engine Configuration (HPC and LPT technology demonstration)</td>
<td>Design, development and ground testing of an advanced geared engine demonstrator: improvement of the thermodynamic cycle efficiency and noise reduction</td>
<td>10.5.4 10.6.4 10.7.4</td>
<td>Engine Demo 2020</td>
<td>44</td>
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<td>IADP / ITD</td>
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<tr>
<td>Engines</td>
<td>Innovative High Bypass Ratio Engine Configurations II: VHBR Middle of Market Turbofan Technology (Rolls-Royce)</td>
<td>VHBR Middle of Market Turbofan Technology</td>
<td>– behaviour of fans at low speeds and fan pressure ratios (e.g. fan stall margin, variable cold nozzle geometries) and structural technology – aerodynamic and structural design of low pressure turbines for high speed operation – Systems Integration of novel accessory and power gearboxes, including oil system and bearing technologies – optimised power plant (e.g integration of engine and nacelle structures, externals and dressings, Noise, Logistic &amp; Build challenges) – compressor efficiency – control &amp; electrical power system technology developments</td>
<td>10.5.5 10.6.5 10.7.5</td>
<td>TRL 4/5 2018</td>
<td>46</td>
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<tr>
<td>Engines</td>
<td>Innovative High Bypass Ratio Engine Configurations III: VHBR engine demonstrator for the large engine market (Rolls-Royce)</td>
<td>VHBR engine demonstrator for the large engine market</td>
<td>– integrated low pressure system for a high power very-high bypass ratio engine (fan, compressor, gearbox, LP turbine, VAN) – engine core optimisation and integration – optimised control systems – ground and flight test of Large VHBR engine</td>
<td>10.5.6 10.6.6 10.7.6</td>
<td>Engine Demo 2017-2019</td>
<td>69</td>
</tr>
<tr>
<td>Engines</td>
<td>Small Aircraft Engine Demonstrator</td>
<td>Small Aircraft Engine Demonstrator</td>
<td>– reliable and more efficient operation of small turbine engines – light weight and fuel efficient diesel engines</td>
<td>12.4.2</td>
<td>18</td>
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<tr>
<td>Engines</td>
<td>[Not for evaluation]</td>
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<td>Other research activities and management: Budget for activities performed by airframer (Airbus) and for</td>
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<td>Eco-Design Transverse Activity</td>
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</table>
| Systems   | Innovative and Integrated Electrical Wing Architecture and Components | Innovative Electrical Wing Demonstrator (including ice protection) | - New actuation architectures and concepts for new wing concepts  
- High integration of actuators into wing structure and EWIS constraints  
- Inertial sensors, drive & control electronics  
- New sensors concepts  
- Health monitoring functions, DOP  
- WIPS concepts for new wing architectures  
- Shared Power electronics and electrical power management  
- Optimization of ice protection technologies and control strategy | 11.6.3 | TRL 5 to 6 between 2018 to 2020+ | 24 |
| Systems   | Innovative Technologies and Optimized Architecture for Landing Gears | Advanced systems for nose and main landing gears applications | - Wing Gear and Body Gear configurations  
- Health Monitoring  
- Optimized cooling technologies for brakes  
- Green taxiing  
- Full electrical landing gear system for NLG and MLG applications  
- EHA and EMA technologies  
- Electro-Hydraulic Power Packs  
- Remote Electronics, shared PE modules  
- Innovative Drive & Control | 11.6.4 | TRL 4 to 6 between 2018 & 2020 | 30 |
### Clean Sky 2 Joint Technical Programme (V5) – Proprietary Information subject to Confidentiality Agreements

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<tr>
<th>IADP / ITD</th>
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<th>ROM EC funding (in M€)</th>
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</thead>
</table>
| Systems    | High Power Electrical and Conversion Architectures | Non propulsive energy generation | - AC and DC electrical power generation  
- AC and DC electrical power conversion  
- SG design for high availability of electrical network  
- Electrical motors for loads applications  
- Integrated motor technologies, with high speed rotation and high temperature material | 11.6.5 (I)  
11.6.6 (II) | TRL6: 2020 | 16 |
| Systems    | Innovative Energy Management Systems Architectures | Innovative power distribution systems, (including power management) | - Electrical Power Centre for Large Aircraft – load management and trans-ATA optimization  
- High integrated power center for bizjet aircraft (multi ATA load management, power distribution and motor control)  
- Smart grid, develop & integrate breakthrough components to create a decentralized smart grid, partly in non-pressurized zone. | 11.6.5 (II) | TRL 4 to 5 between 2019 & 2020 | 8 |
| Systems    | Innovative Energy Management Systems Architectures | Innovative power distribution systems, (including power management) | - Electrical Power Centre for Large Aircraft – load management and trans-ATA optimization  
- High integrated power center for bizjet aircraft (multi ATA load management, power distribution and motor control)  
- Smart grid, develop & integrate breakthrough components to create a decentralized smart grid, partly in non-pressurized zone. | 11.6.5 (II) | TRL 5 & 6: from 2018 to 2020+ | 33 |
<table>
<thead>
<tr>
<th>IADP / ITD</th>
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<th>Technologies</th>
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</table>
|               | Systems                                              | Innovative Technologies for Environmental Control System | - Electrical Power Centre – load management optimization  
- Health Monitoring, DOP compliant  
- New generation of EECS including a global trans ATA visionable to answer the needs for load management, Inerting systems, Thermal Management, Air quality & cabin comfort  
- Development / optimisation of Regional A/C EECS components for full scale performance demonstration  
- New generation of cooling systems for additional needs of cooling | 11.6.6 (I) | TRL 5 & 6: from 2018 to 2020+ | 28                     |
|               | Systems                                              | Advanced Demonstrations Platform Design & Integration | Demonstration Platform – PROVEN, GETI & COPPER Bird®, AVANT, IWT  
- Use to maturate technologies, concepts and architectures developed in Clean Sky 2 or from other R&T programs and integrated in Clean Sky 2  
- Large demonstration platform  
- Optimization and validation of the thermal and electrical management between the main electrical consumers | 11.6.7 (II) | Large test platform to reach higher TRL level for electrical equipment / systems (from 4 to 6 dependin of the | 16                     |

2015 Clean Sky 2 Joint Technical Programme (V5) – Proprietary Information subject to Confidentiality Agreements
### IADP / ITD

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<th>Complete by</th>
<th>ROM EC funding (in M€)</th>
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</table>
| Systems          | Small Air Transport (SAT) Innovative Systems Solutions | Small Air Transport (SAT) Activities | - Efficient operation of small aircraft with affordable health monitoring systems  
- More electric/electronic technologies for small aircraft  
- Fly-by-wire architecture for small aircraft  
- Affordable SESAR operation, modern cockpit and avionic solutions for small a/c  
- Comfortable and safe cabin for small aircraft  
Note: budget has been identified for specific SAT work inside Systems. However, synergies with main demonstrators and specific work still have to be worked upon | 12.4.3 | 20 |
| Systems          | ECO Design | ECO Design activities | Refers to ECO Design chapter | ECO Design | 5 |
| Systems          | Management: Included in demonstrators | | | | 0 |

Total: 249
### Technology Evaluator (TE)

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<th>IADP / ITD</th>
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<th>Technologies</th>
<th>Reference Chapter</th>
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</thead>
</table>
| Technology Evaluator (TE) | A systematic overall approach to the Technology Evaluation process and monitoring activity |  | – Progress Monitoring of Clean Sky 2 achievements  
– Evaluation at Mission Level of particular ITD outputs  
– Impact Assessments at Airport and ATS Level | 12 | 17 |

The funding required for the Technology Evaluator will be taken from the Total Clean Sky 2 EC funding as a “tax in advance”.

### JU Running Costs

The funding required for the running costs of the Clean Sky 2 Joint Undertaking will be taken from the Total Clean Sky 2 EC funding as a “tax in advance”.

### Total CS2 EC funding:

1.755

### Eco-Design Transverse Activity

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| Eco-Design Transverse Activity | An overall innovative approach and "agenda" for Eco-Design activity in the CS2 Programme |  | Eco-Design activities are embedded in all IADPs and ITDs. They are detailed in Chapter 13. Thus, a dedicated funding for Eco-Design is reserved inside each IADP’s and ITD’s funding. 
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<td>Small Air Transport (SAT) Transverse Activity</td>
<td>An overall innovative approach and &quot;agenda&quot; for Small Air Transport activity in the CS2 Programme</td>
<td></td>
<td>Small Air Transport (SAT) activities are part of Airframe, Engines (WP7) and Systems ITDs and are detailed in Chapter 14. The co-ordination of all SAT activities will be established in the Airframe ITD. The funding required for the Small Air Transport Transverse Activity is 67.95 M€ in total.</td>
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6 Large Passenger Aircraft IADP

6.1 Going beyond Clean Sky

The Smart Fixed Wing Aircraft – Integrated Technology Demonstrator (SFWA) in Clean Sky is providing the best evidence that a R&T programme seeking to push new breakthrough technologies for large transport aircraft towards applications is greatly enhanced in a framework that allows the conduct of large-scale demonstrations on ground, in dedicated rigs and facilities, and with large or full-scale flight tests. When combined with associated numerical and analytical studies, and furbished with the related capabilities and capacities to conduct the corresponding conceptual and detailed design work, the inherent uncertainties and risks of new technologies can be most effectively and efficiently understood, technically managed and removed.

Within Clean Sky, key technologies for the fuel efficient, low drag “smart laminar wing”, and a number of new technologies to integrate the most efficient, most advanced propulsion systems for commercial large transport aircraft of the future are passing the critical steps of proving and validation in the SFWA ITD. Most of the key technologies in the Programme, having typically been injected at Technology Readiness Level (TRL) 2 or 3 are, at around half way through the Programme, at TRL 4 or 5. As an example in SFWA the target for the smart natural laminar wing and a new low speed vibration load control is to reach TRL 6. For the innovative noise shielding empennage, and the smart flap the target TRL is 5, and a down selected set of active flow control technologies. For the in-flight demonstration of the CROR propulsion concept the target TRL is 4 to 5 “+” as some important items of structural and system integration cannot be validated within the planned lifetime of Clean Sky.

One of the key drivers for the implementation of the IADP in Clean Sky 2 on top of the well-proven ITD is a specific result of lessons learned from SFWA. Reaching TRL 6 for an individual technology through validation and demonstration in ground and flight tests at relevant scale and under operational conditions in a multidisciplinary approach does not typically provide any evidence and proof of the risks and potentials of the technology when integrated with other key technologies at the whole aircraft level. For example - what are the risks and the technical potential when combining, for example, an entirely new wing, an entirely new propulsion system and a new innovative empennage design together? This type of question is the reason for planning the IADP in Clean Sky 2, the setup and content of the “Large Aircraft IADP” has directly emerged to provide the answer to that question.
6.2 Challenges to be tackled for Large Aircraft in the Horizon 2020 Period

Today, Europe benefits from a 40% share of the global aerospace market with short/medium range aircraft making a very large contribution to this success. The next generation of short/medium range aircraft is key to the future of aviation in Europe. This aircraft type will remain core to air transport and essential to efforts to decrease aviation CO₂ emissions for the foreseeable future. Mounting competition from existing and new entrants means that the European sector can only survive by being a global leader in terms of innovation and product performance, at affordable costs and with high volume availability. A significant part of the current Clean Sky research activity is focused on this aircraft class: e.g. the laminar-flow wing and open rotor propulsion, resulting in flight tests at the level of each separate system.

Clean Sky 2 is building on these latest results and is setting out to provide the required platform in which these research matters can be addressed in an integrated and fully representative manner. It provides the essential next research step of verifying and demonstrating how the potentially promising breakthrough technologies must be combined to effectively reveal their full synergies and their potential for future generations of aircraft. In this regard, the project will be decisive for delivering the required technology innovations that will make these new generations of European aircraft possible. By maturing these technologies on a research platform at European level, it is realising the potential for market adoption in the decade thereafter.

Compared to the year 2014 technology state-of-the-art a minimum of 20% reduction of specific fuel burn respectively reduction of CO₂ emission at mission level is set as a clear target for the large-scale integrated demonstrations in the LPA-IADP, addressing technologies to be introduced to next generation aircraft with envisioned market entry in the 2025 to 2030 timeframe.

Based on the status of the current R&T results in Clean Sky, the CROR engine concept has the potential to contribute to more than half of this improvement. Triggered by the recent very promising results in the SFWA-ITD substantial single digit drag improvements are expected to be drawn from an extended use of the natural and hybrid laminar technology applied to next generation large passenger aircraft. A further substantial improvement will be contributed by weight reduction stemming from a fully re-thought fuselage-cabin-cargo integrated approach, with an entirely new, coherently developed structure and systems approach. The next generation cockpit shall capitalize the capabilities of the year 2020+ air traffic management, namely to operate large transport aircraft seamless on unprecedented environmental friendly flight trajectories.

Based on the current market forecasts a reasonable projection is that the large aircraft demonstration platforms of Clean Sky 2 will deliver solutions that can impact over 75% of the fleet needing replacement from 2025 onwards. The IADP will bring a highly significant contribution to the prime Clean Sky 2 environmental and socio-economic targets: protecting the environment whilst ensuring sustainable mobility. In explicit terms, it will:

- Facilitate the greatest possible environmental benefits of environment protection in terms of reductions of CO₂ emissions per passenger-kilometer as well as NOₓ and noise emissions.
- Allow the entire European aviation value chain to jointly collaborate on integrated platforms. In Clean Sky the large commercial aircraft activities engage 16 separate EU member states. It is reasonable to project that a similar level of engagement will occur for these activities in Clean Sky 2.
- Help to maintain and extend European industrial leadership and to be recognized globally as innovative, sustainable and competitive, thereby delivering the largest contribution to employment and economic benefits.
- Target the most challenging aircraft technology breakthroughs for which well-known market requirements exist and the volume, growth and economic scale will lead to substantial long term investments and the creation of high technology jobs in Europe.
- De-risk the development of breakthrough technologies and so ensure safety and security, leading to the setup and continuous improvement of unprecedented levels of safety.
- Align European research and innovation strategies amongst all stakeholders and allow pushing forward efficient research, technology development and demonstration with appropriate infrastructure, testing capabilities and funding.
6.3 The Role of the Large Aircraft IADP

By definition, technologies that will be brought into the ITDs of Clean Sky 2 have already successfully passed a prior down selection and have a TRL of at least 2 or 3. In contrast, some technologies will be brought into the IADP at TRL of 4 or even 5. This gives the IADP the capacity to deliver technologies integrated in combination and up to TRL 6 over the lifetime of Clean Sky 2.

The explicit role of the Large Aircraft IADP in Clean Sky 2 is to provide:

- Target technology scenarios for combinations of technologies;
- A large-scale integrated demonstrator platform to systematically mature breakthrough technologies in combination, to achieve high TRL of typically 6 with the goal to achieve an equivalent System Readiness Level (SRL);
- Large demonstrators on ground and in flight, at size and scale representative for cases of potential future application, with complementary rig and ground tests in wind tunnels;
- The environment to create, establish, mature and calibrate tools and numerical simulation means to facilitate the transfer of results into scenarios different to the test or demonstration cases, and to facilitate “virtual” testing in addition to the designs and physical setups tested on ground and in flight.

The technologies to be taken into the Large Aircraft IADP will be selected in order to feed into the target 2025-2030 technology scenarios:

- Best candidate high TRL technologies emerging from Clean Sky, in particular from the Integrated Technology Demonstrators SFWA, SAGE, SGO and Eco-Design;
- High potential technologies injected from other R&T programs, national or European funded, being at appropriately high TRL to be rapidly pushed forward to TRL 6;
- Additional “enabler” technologies required to link or combine the technology bricks to be matured and validated.

The key issues to be tackled and answered in reaching for TRL 6 are to:

- Fully understand the physical potential of the target technologies in combination,
- Demonstrate the maturity of the technology for all operational cases at representative size and functionality, where appropriate with individual feature demonstrators or in combination;
- Demonstrate the impact of technologies to support the elimination of operational disruptions due to maintenance and to enable the optimization of the value chain for the main actors (airlines, MROs, suppliers, OEMs) beyond 2020
- Understand the value for the passenger and freight, with respect to comfort and operational aspects;
- Answer all questions related to industrial introduction and application with regard to manufacturing, production ramp up, complexity of tooling and related efforts.

In addition, a systematic understanding for dynamically-scaled demonstration, namely the physical laws, the range and limits of validity, accuracy and representativeness will be brought together in a dedicated IADP workspace.
6.4 Set-up of the Large Aircraft IADP

To be able to most effectively address the scope of challenges towards a next generation large commercial transport aircraft in the context of Horizon 2020, the Large Aircraft IADP embodies three separate areas of integrated demonstrators:

- Large Aircraft IADP Platform 1 “Advanced Engine and Aircraft Configurations”
- Large Aircraft IADP Platform 2 “Innovative Physical Integration Cabin – System - Structure”
- Large Aircraft IADP Platform 3 “Next Generation Aircraft Systems, Cockpit and Avionics”

Coherence between the three platforms will be provided by a direct link between the platform leads. The technology scenarios, which will set the frame of the demonstrations to be selected, prepared and performed, will be provided by Airbus, to be discussed and adjusted with the participating Consortium Members. The high-level work breakdown structure is displayed in Figure 6.1, the content of the individual work packages technology bricks and demonstrators will be outlined in the following chapters.

Technology Assessment and Interface to Transversal Activities Clean Sky 2 “Technology Evaluator” and “Eco-Design” – WP0.1, WP0.2 and WP0.3

The progress in the research and development work on the different subjects and key technologies will be monitored with internal technology assessments in virtually all work packages with individually tailored tools and methods. The outcome of these assessments is typically inherent part of the TRL process. However, these individual assessments do provide data that have to be further processed and combined to assess the value of a technology at major component level. In order to assess the value of a new key technology progressively developed and matured in LPA, data for the Technology Evaluation at Clean Sky 2 level will be fed by the individual LPA work packages into a dedicated work package LPA WP.01 for further processing. In the LPA-IADP, it is planned to coordinate and manage the interface to the Clean Sky 2 TechnologyEvaluator, the Eco-Design Platform and to the ITDs as a cross-sectional function.

As first Transverse Activity, the Technology Evaluator (TE) will receive inputs from the LPA-IADP. The progress of LPA platforms will be monitored against well-defined environmental and socio-economic benefits and targets. LPA will provide verification and validation of the proposed aircraft designs. The tool PANEM, gathering A/C trajectories, noise and emission prediction, developed in Clean Sky will be used to perform mission assessment. What is new compared to Clean Sky is the continuous assessment which will be performed by LPA directly, with - versus time - an improvement of the technologies assessment and a decrease of uncertainties concerning the technologies benefits. The results will be reported in agreed intervals to the TE. If new opportunities are found in the ITDs or by de-risking new technologies, they will be introduced into the aircraft model and taken into consideration. The concept aircraft models will be the inputs for Impact Assessments at Airport and ATS Levels.

As second Transverse Activity, Eco-Design will be treated in a specific work package WP2.0 in LPA to manage the interface to the ECO lead function allocated in the Airframe ITD. However, a great variety of Eco-Design relevant technical activities are directly included in the technical activities throughout virtually all LPA chapters planned and directed in the associated work packages. These activities will not be mentioned as separate items in the work description of the following three technical LPA chapters in this document, but included.
Examples for related activities that will be covered in the LPA Work Programme include:

- Next generation integrated fuselage concept, structure, cabin, cargo and overall system integration;
- Advanced materials for Cabin and Cargo equipment and monuments – Life Cycle Assessment;
- Next generation “smart” laminar wing integrated structural demonstrator. Use of materials, manufacturing and assembly processes;
- Large Passenger Aircraft “Factory of the future” industrial processes (machining, welding, bonding) use of materials, chemicals, energy, water, etc.;
- Repair methods and processes.

Research and technology activities in LPA will typically build on a quite mature status of technology developed before up to a TRL level of typically 2, 3, or even 4. Related inputs are provided through intermediate or end results of other R&T and R&D programmes outside of Clean Sky, but will also include intermediate or final outcomes from Clean Sky 2 ITDs.

It is firmly planned that technical interfaces are directly managed through links between the related technical work packages, and not piped through a single line work package as connection line. However, a high level monitoring of these connections and interactions shall be done through a dedicated work package WP0.3 to facilitate and promote cooperations where required, and to boost the functioning of Clean Sky 2 as one programme.
Figure 6.1 - LPA-IADP Work Breakdown Structure
6.5 Platform 1 “Advanced Engine and Aircraft Configurations”

Taking the year 2000 as reference for the Vision 2020 “ACARE Goals”, it was and still is the common understanding that an enormous potential for drag reduction, fuel burn and noise emission for large transport aircraft primarily lies in just a few key airframe and engine technologies provided that the substantial operational and industrial risks can be fully understood and managed.

From a number of major R&T programmes, it is well-known that a simple plug-in of a new technology to an existing aircraft concept, e.g. the introduction of an innovative engine concept, has significant consequences for the entire product with respect to performance, operation and industrial production, and use case. If more than one technology with improvement potential are merged, the resulting consequences are much more complex and significant improvement potentials of an individual technology can eventually lead to an overall much smaller benefit or even a negative net outcome at aircraft level resulting from measures, concept or design changes due to the integration of such a specific technology.

Any addition of a major new technology to a currently well-known transport aircraft configuration may lead to the need for significant change of the configuration through most if not all disciplines. Achieving a significant net gain for a future generation aircraft, and combining a number of individual step-change technologies requires a substantially rethought, potentially disruptive aircraft configuration. The Advanced Engine and Aircraft Configuration Platform of the Large Aircraft IADP provides the integrated demonstration platform for these combinations of best candidate, highly mature technologies.

Currently, there are two candidate propulsion systems able to push the overall aircraft efficiency beyond the state of the art geared turbofan technology with up to double digit fuel burn reduction figures: the Contra Rotating Open Rotor, and the Ultra High Bypass Ratio Turbofan. The integration of each of these propulsion technologies requires major changes to the current aircraft architecture. The integration of a radically new smart wing in combination with an innovative engine concept and other new technologies can only be successfully managed through an integrated validation and demonstration process.

6.5.1 Platform 1 Setup and Activities

Platform 1 is built from six essentially distinct work packages of which each is aiming for a specific demonstrator – or in case of WP1.3 demonstration technology – to validate or facilitate a carefully down selected, most advanced fuel saving propulsion technologies, technologies with high aerodynamic respectively drag reduction and weight saving potential towards potential application in a next generation large transport aircraft. In many of these cases, these technologies result in a substantial deviation from the “conventional” configuration of an aircraft. This means that a test under realistic conditions requires a severe modification of an existing test vehicle or the design and the building of a complete standalone test item. The demonstration articles, vehicles and means in all individual work packages are cautiously tailored to provide a key element, or the key element to accomplish TRL 6 for the targeted technology.

In addition, Platform 1 includes a work package to test and mature operational procedures in combination with facilitating technologies in a fully relevant environment.
WP0 in Platform 1 deals with the management and harmonization of the overall technical planning, progress of work, coordination of the partner work shares, resources and management of risks in the Platform 1 demonstration work packages. The role of WP0 also includes the coordination of the interfaces and interactions to the Clean Sky 2 Technology Evaluator, Eco-design work packages as well as interfaces to Clean Sky 2 ITDs.

6.5.2 “CROR Demo Engine FTD” – WP1.1

I. Relevance of the Technology for H2020

The CROR propulsion technology is the key contributor to the overall aircraft package that can offer an improvement in fuel burn efficiency in the order of 15% - 20% compared to the best today’s technology status. With best performance at cruise speed of Ma0.72 to Ma0.76, a huge amount of joint R&T activities to develop and integrate the CROR engine concept for short and medium haul large transport aircraft have been launched in Clean Sky since July 2008. Despite significant progress, addressing the main issues of certification, cabin and community noise, as well as various aspects of the propulsion system integration and the engine design led to an extension of the very ambitious programme targeting for TRL 6, including a major flight test campaign with full size demo-engines. The development of the flight worthy test engine was not part of Clean Sky from the beginning.

With a major review of the CROR concept results achieved so far in the 2013 summer, the key element to accomplish TRL 6, the flight test of the demo-engine, now including the building of a full size flight worthy engine shall now be conducted in WP1.1 of the LPA IADP. In addition to the engine demo activities, the WP 1.1 will also address an activity dedicated to the Non-Propulsive Energy (NPE) generation for new engines architectures; in order to identify the most relevant solution for NPE approach for the next generation of engines and aircrafts. Current assumption is to use the Airbus A340-300 MSN001 test aircraft as flight test vehicle, with one full size CROR pusher engine attached to a representative pylon and engine mount installed at the port board side of the rear fuselage.

In addition to the engine demo activities, the WP 1.1 will address the activity dedicated to the Non-Propulsive Energy (NPE) generation for new engines architectures; in order to identify the most relevant solution for NPE approach for the next generation of engines and aircrafts. The perimeter for NPE activities will cover ‘classical’ approaches (i.e. power off-takes on main engines) and other approaches dealing with the ratio propulsive/non propulsive power needs at aircraft level.

II. Demonstration Objectives

The key objectives of the WP1.1 demonstration are to:

- Validate the aerodynamic efficiency versus noise level for a full size integrated CROR pusher engine under operational conditions including interaction with pylon wake
- Demonstrate and validate the viability of assumptions for the chosen engine concept like power gearbox, blades, pitch control, lubrication system, energy and thermal management, engine control concept. The domains that will be analyzed for engine benefits are dynamic and mechanical behaviour, operability and transients over the whole flight profile, vibrations, blade noise characteristics at aircraft scale with installation effects, etc.
- Demonstrate and validate a pylon concept and system integration, in particular addressing loads, vibration, and noise attenuation technologies in real size
Clean Sky 2 Joint Technology Initiative in Aeronautics

- Demonstrate and validate the selected propeller and blade design
- Synthesize available data from Clean Sky with CROR demo-engine flight test data, re-calibrate tools analysis and converge results to accomplish TRL 6
- Take decision for second engine concept towards flight test, establish and launch related plan in WP1.1;
- Interface with WP1.2 to deliver CROR engine data from ground and flight tests.

III. Added-value versus state-of-the-art

All current advanced engine concepts which are candidates to be integrated on large transport aircraft are based on the principle of High, Ultra-high Bypass Ratio (UHBR) or Geared (GTF) turbofans. After a short, intense feasibility phase conducted with two types of engines in the early 80ties of the last century, the approach to develop a CROR engine concept for this class of aircraft with a majority of activities allocated in Clean Sky is absolutely unique in the world.

For large short and medium range aircraft, the first GTF engines will be the most advanced and fuel efficient state-of-the art solution presumably entering service in year 2015. Compared to the GTF, the CROR concept is holding a potential of up to 15% further fuel burn reduction. To materialize this potential, Clean Sky 2 has to deliver a firm proof that the CROR engine concept can be produced, integrated and operated in an industrial environment with efforts competitive to other latest state-of-the-art concepts.

With clear intention to rethink the system architecture and the use and management of aircraft on-board energy for next generation aircraft, the de-correlation of propulsive and non-propulsive energy is considered an important contributor to a further increase of the overall aircraft energy efficiency but also profitability. Taking this approach properly into account at the engine lay-out, sizing, and required modes of operation, the ambition is to gain additional percentages of fuel burn performance for either CROR or UHPE concepts.

IV. High-level WBS and work-sharing

The work breakdown structure of WP1.1 is tailored straight to prepare, conduct and analyse the flight test of the CROR engine under the assumption that the preliminary design of the test aircraft is accomplished in Clean Sky SFWA already. WP1.1 will address the engine integration into the overall aircraft, thermal management, static and dynamic loads transfer, aerodynamic integration, but also including the power-off-take technology. WP1.1.2 will host most of the activities to guarantee and demonstrate the aircraft safety with respect to Permit to Fly including VnV. WP1.1.3, under Snecma leadership, will host most of the activities to prepare, manufacture, assemble, ground test, qualify and certify the test engine modules along individual maturation plans and finally the fully assembled engine for flight, as well as all complementary activities to maintain the engine during the flight test campaign. Also NPE activities will be hosted in WP 1.1.3 including the requirements for non-propulsive energy generation.WP1.1.4 will host all Airbus activities to design, manufacture and integrate to the CROR engine a second set of propeller blades offering an alternate mean to comply with CROR aircraft certification rules. WP1.1.5 will deal with the pylon concept for the flight test demonstration, while keeping the concept as independent from the A340 test case, but representative for a potential future pylon development. WP1.1.6 will address all specific design activities such as design and manufacturing of aircraft structural reinforcement. WP1.1.7 will address aircraft systems modifications and interfaces with CROR engine systems. WP1.1.8 “Aircraft integration” will specifically include the physical conversion, and upgrading from the ground test engine to the flight test engine, and all related performance testing, assessment, and pass-off tests. The integration of the flight demo engine to the test aircraft will be done in close cooperation between Airbus and the engine manufacturer.
WP1.1.9 contains all activities directly linked to the flight tests, including the preparation of the flight tests planning, flight tests request, flight clearance tests, flight tests conduct activities and flight tests results delivery. There will be a close link between WP1.1.9 and WP1.1.8. Also included are the activities to prepare, install and operate the flight test instrumentation and the data analysis. WP1.1.10 addresses an activity dedicated to the Non-Propulsive Energy (NPE) generation for new engines architectures; in order to identify the most relevant solution for NPE approach for the next generation of engines and aircrafts.

Airbus will hold a majority of the work shares related to the preparation, operation and refurbishment of the flight test aircraft, Snecma will hold a major share to prepare, build, test and operate the test engine. Core partners and Call for proposal partners shall be invited for engagement on a wide scope of WP1.1. activities, specifically related to detailed pylon development, engine mount and vibration damping technologies, development and operation of flight test instrumentation, rotating frames, pitch control, power gear box and power turbine.
V. Planning roadmap, targeted technology readiness levels

The planning roadmap is synchronized with the entry of initial deliveries from Clean Sky SFWA and SAGE, namely the conclusive availability of the preliminary design of the test aircraft, and the CROR ground test engine critical design review, which will include most of the definitions required to start launch the preliminary design of the flight test engine demonstrator. A differentiation analysis between ground and flight test engine from the engine manufacturer and the airframer view point will parallel the transfer from Clean Sky to Clean Sky 2.

With a phased start of the preliminary design of the flight test engine in autumn 2016, and the detailed design of modifications of the A340-300 test aircraft in autumn 2017, a baseline of 6-month flight testing is planned end of 2020 to first quarter of 2021. In addition, a handover of the special flight test instrumentation for the CROR demo-engine flight test from SFWA to the LPA-IADP WP1.1 is scheduled early 2017.

The maturity level of the NPE technology will reach TRL level of 4 to 5 the end of 2019, according to the selected demonstration to be performed, i.e. depending of the trade-off studies outcome.

VI. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

As there is no CROR engine development planned in the Engine ITD, and no specific CROR engine related system activities planned in the Systems ITD, WP1.1 will be mostly dependant on a proper interfacing to SFWA and SAGE in Clean Sky. In addition to the main activities to integrate, flight test and validate the engine with respect to its primary function as propulsion power plant, a dedicated part of the work plan will deal with associated non-propulsive energy generation for the CROR engine. Considerations of system allocation (in engine, engine nacelle, pylon, fuselage) will be made and agreed between Airbus and the engine manufacturer with respect to the main system concept (more electric, all electric) in the course of the work plan. The development of this technology is
VII. Synthesis of added value with respect to H2020 targets

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<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
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<tr>
<td>D1.1. CROR Demo Engine Flight Test Demo &amp; NPE Demonstration</td>
<td>CROR Performance Noise, Vibration</td>
<td>CO₂: - 15 to - 20%</td>
<td>Green operation, Cost of operation, community noise, passenger comfort</td>
<td>Reduce dependency on fuel price</td>
<td>2020</td>
<td>Airbus / Safran CPs (large aero-industry, suppliers, RE’s) CFP Partners (RE’s and SMEs)</td>
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<td></td>
<td>NPE activities: CROR, UHPE, optimised NPE approach, new A/C architectures</td>
<td>CO₂: - 2 to 5%</td>
<td>Global approach for new architectures optimisation, enablers for new functions (industrial differentiation)</td>
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6.5.3 Advanced Engine Integration Driven Fuselage” – WP1.2

I. Relevance of the Technology for H2020

New, eco-efficient aircrafts are challenged by a demand to significantly reduce the CO\(_2\) and NO\(_x\) strain. To achieve these goals, Airbus is exploring new configurations for integrating innovative advanced engine on the aircraft. Most promising advanced engines as the CROR, Boundary Ingestion Layer (BILL), UHBR, multiple fan and similar concepts cannot be integrated simply by replacing engines of the current generation, but require a substantial change of the principle aircraft configuration. Results from recent research programmes have provided much evidence that many of these concepts do lead to better gains of ecologic and economic efficiency by installing them on the rear end of the fuselage.

The advantage of installation on the rear fuselage is motivated by the favourable spatial integration conditions and in particular, for large fan diameters or multiple fans, which is key for achieving unprecedented fuel efficiency.

In the case of unducted engine architecture as the CROR, the rearward shift of the engines away from the wing provides additional advantages in cabin noise and passenger comfort and safety improvement.

In other cases, as the Boundary Layer Ingestion concept, in which the engines are buried in the fuselage shape, additional aerodynamic benefits can be achieved through a carefully tailored integration to the aircraft fuselage.

As shortly explained in WP1.1, one of the most valuable technologies is seen in the Contra Rotating Open Rotor propulsion system, which may set the basis for a game changer of a new short range aircraft concept. These engines are currently the only candidate to offer a fuel burn efficiency that is in the order of 15% - 20% versus the most advanced turbofan or geared turbofan engines, becoming available in the market in the next few years. A key issue to materialize this potential is to successfully manage the integration of such an engine into the aircraft.

One of the most critical challenges of such innovative engines mounted on the rear fuselage is safety, respectively certification requirements in the case of Uncontained Engine Rotor Failure (UERF). High energy debris can be released and impact the aircraft at high speed, challenge the structure integrity and the safe continuation of flight and landing, endangering passenger’s life.

Another challenge is the introduction of high dynamic loads to the aircraft primary structure via a large pylon that is connected to the engine and the fuselage with a highly solicited interface and, very high demands in vibration and potential fatigue issues. Treatment of engine associated vibrations induced on structure is also necessary to assure passenger comfort and A/C safe operability/pilotability.

An additional key enabling aspect is the multi-functional and efficient physical integration of such innovative engine architectures into the aircraft design (structure & systems), assuring feasibility and overall economic efficiency (manufacturing and operational cost) competitively compared to turbofan aircraft conventional configurations.

The rearward positioning of the engine requires to substantially re-design the systems and structural architecture of the aircraft. This is mainly due to the significant impact on the centre of gravity of the aircraft, the changed space allocation conditions in the rear fuselage and the load conditions and levels coming along with the integration of engines of ultra-high bypass ratios (ducted or unducted). Linked to a rearward engine positioning
any relocation of systems (e.g. the air condition packs, pre-cooler) from established locations in the airframe into the rear fuselage requires also a careful re-design of the inlets and outlets for cooling and ventilation purposes. This situation might be additionally challenged, in terms of space allocation, in case of a growing spatial envelope of the auxiliary power unit caused by an increased power generation requirement.

Moreover, a successful integration of such engines also requires to closely monitor the resulting noise levels (cabin and external) and safety conditions (e.g. structural and critical systems exposure in case of rotor blade release through engine failure) associated with such engines mounted on the rear fuselage. Any structural reinforcement or shielding measure to protect the airframe against uncontained rotor failure, caused by either one of the co-located engine or the auxiliary power unit, will be a result of an integrated design approach combining the needs and any synergies of both systems.

As a result of an integrated and synergetic design approach, any considered shielding strategy for the airframe will consider not only impacts by uncontained rotor failure but also impacts caused by ice shedding, tyre debris or hail and bird strike as well as noise shielding requirements.

The plan is therefore to develop efficient measures for structural shielding reinforcement based on innovative material technologies and architectures, including noise shielding functionalities. This task requires going beyond the state-of-the-art manufacturing methods and processes to master the aforementioned challenges. Proceeding this way, the expected high integration level will be achieved and as a result, the competitive advantage of integrating such propulsion systems is assured and the final product can be prevented from degradation that would be otherwise caused by a low level of applied design integration and/or the use of non-qualified manufacturing and maintenance methods.

In order to achieve this goal, one of the main objectives is to develop full CFRP rear-end structures that will provide higher level of integration at lighter weight and improved performance regarding vibrations and fatigue. Also best impact tolerance performance and residual strengths after damage could be reached on such composites structures with the advantage of being able to combine multilayer materials, lightweight but with very high impact and multifunctional performance. Innovative composite tailoring as the braded and woven technologies are demonstrated to be very efficient in structural parts both for impact and large damage. Composite structures also enable the integration of Structural Health Monitoring technology (SHM) that is able to reduce the maintenance cost and the risk of failure on such solicited structures. Also damping technology can be embedded on such composites to attenuate impact and vibrations transmission on the structure.

In order to develop the required technology maturity level for such key enablers in the aircraft development process, it is mandatory to perform validation at representative scale. It is mandatory to develop the required test capabilities at full scale both for virtual and physical testing purposes (impact, static, vibrations, systems integration and operability). Proceeding this way, the guiding certification and safety requirements of such highly integrated technologies as well its economic efficiencies can be determined and validated early in the development phase.

The rear-end demonstrator (and subcomponent test) proposed in this work package answers to the abovementioned demands. These demonstrators shall be built up for validation purposes regarding safety/certification and structure/systems integration concepts up to full scale, aiming for technology readiness at TRL 4 to TRL 6.
The result of the “Advanced Engine Integration Driven Fuselage” demonstration will deliver a key enabler to acquire a 15-20% fuel saving potential in combination with the capabilities to design and produce a competitive industrial solution for a short and medium haul next generation large passenger aircraft.

Figure 6.3 – Airbus R&T concept study with rear mounted open rotor engines

In addition, a full CFRP rear end covering this scenario provides weight savings, yields additional fuel savings and provides supplementary assistance for environmental preservation. The proposed demonstrator will allow mastering associated industrial challenges and risks and will contribute in a significant way to generate the know-how necessary for maintaining and extending European leadership in this field.

II. Demonstration Objectives

The main objective of this WP is to validate critical disruptive technology, required to secure safe and efficient CROR integration on rear end mounted aircraft, at representative scale, to reach TRL 6 readiness level.

The first objective is to demonstrate that disruptive structure & shielding architecture reaches necessary safety level requested by certification, with minimum penalty at aircraft level. The rear end demonstrator provides required representative framework for performing static, fatigue and dynamic test to validate that structure and critical interfaces are able to sustain required loads conserving integrity. In addition, it provides representative hardware scale to perform CROR engine debris impact test to demonstrate structural integrity after impact.

The second objective is to demonstrate the feasibility and efficiency of the multifunctional physical integration of structure and systems to avoid integration showstoppers and secure minimum cost and penalty both at manufacturing and operability. A rear-end demonstrator including systems will provide the required representative environment to perform manufacturing and assembly testing system performance testing and operability process validation.

An additional objective of the rear-end demonstrator is to fulfil “transversal” needs of partial or total testing for other technologies necessary for innovative engine integration as cabin acoustics, vibration propagation and vibration comfort.

The detailed objectives of this work package are the following:
Demonstrate the loads capability of the structural solution at full scale with representative static, fatigue and dynamic loads, including a down selected fully representative rear-end including pylon & engine mounts, rear-end fuselage, tail cone, T-tail and its interfaces.

Demonstrate an engine integration solution fully compliant with certification rules, namely primary structure and shielding against uncontained engine debris release (blade release from main engine and auxiliary power unit blade and disc release, ice sheading, etc.) and relevant engine failure cases.

Validate a structure and system integration concept for an advanced engine at a full CFRP fuselage rear end and pylon, including tail cone and APU, in particular addressing aspects of industrialisation, like manufacturing, assembly and maintenance issues.

Develop and demonstrate fuselage vibration and acoustics response for low, medium and high frequency ranges to validate other important aspects linked to vibrations such as passenger comfort, system safety, interior noise, etc..

Development of test capabilities both physical at full scale and virtual for various purposes such as static, fatigue, vibrations, impact, system integration and operability.

Develop, mature and demonstrate concepts for structural health monitoring.

Demonstrate repair technologies.

III. Added value versus state-of-the-art

The CROR propulsion system is currently the only candidate to offer a fuel burn efficiency that is in the order of 15%-20% versus the most advanced turbofan or geared turbofan engines. A key issue to materialize this potential is to successfully manage the safe and efficient integration of such an engine into the aircraft.

Beside the upcoming disruptive design features, the major technological burden is the safe and efficient way of CROR integration mounted onto a rear end fuselage in the favoured Pusher aircraft configuration and with multidisciplinary benefit. Accompanied by challenges such as pylon and nacelle integration onto the rear end fuselage, manufacturability, sustainability against engine and propeller debris, other stakeholders like system integration and interior noise are highly affected by this configuration as well.

One important challenge is the certification rules that are not completely defined yet for such engine configuration and in particular, for the chapters linked to the safety in the case of engine burst or blade debris release. There are well-defined and known state-of-the-art rules for propellers and turbofan engines but rules for such innovative propulsion system as the CROR or other innovative engine are not matured, requirements or means of compliance that should drive the design are therefore not available. Special attention and support should be performed to the development of such certification rule in collaboration with authorities and other industries, as they will drive the resulting demonstration. The test that will be performed to the rear-end ground demo should be driven by the maturation of such rules. At the same time, the definition and results from such test will also be refed into the consolidation of the certification and could become reference for the definition of means of compliance for certification demonstration. This interdependency shows that proposed rear-end ground demo is a major step in the development and maturation of required new certification rules for non-conventional propulsion system as the CROR engine.

Regardless of the mentioned non-mature certification rules, the authorities will not allow a degradation of the level of safety reached by the state-of-art turbofan. In order to achieve such level of safety with the innovative engine configurations, the development and efficient implementation of advanced shielding technologies that
will reduce the damage after impact in the case of engine burst or blade or other debris release is mandatory. As a result, an important part of the demonstrator will address this innovative shielding development and validation. As already mentioned, the structural shielding design will consider requirements and constraints associated with debris protection (e.g. tyre debris, bird strike, etc.) as well as noise shielding.

An additional important challenge of this configuration is linked to the main structural interfaces on such configuration as the pylon to fuselage, engine to pylon, and VTP to fuselage. Those structures are driven by the open blades of CROR/innovative engine, defining non-conventional architectures for such interfaces, with much challenging requirements compared to conventional turbofan engines installations on the rear fuselage.

It is quite obvious that any novel and at the same time compatible system architecture for an installed engine of large bypass ratio at the rear-end represents an important challenge with respect to spatial integration, ventilation and aerothermal issues.

Associated to these challenges, important objectives will also be to develop and demonstrate efficient implementation of innovative composite rear-end structures that will provide higher level of integration for systems and multi-functional capabilities. They provide lighter weight structures but with improved performance regarding highly loaded non-conventional architecture and interfaces associated with innovative engine integration. Non-conventional composite structures also provide advantages to consider integrated multifunctional features such as new structural shielding means based on multilayer or tailoring technology, health monitoring, embedded damping and others. Such advanced technologies will be required to reach the targeted level of efficiency to avoid a degradation of the initial advantage of innovative engine technology. These innovative technologies are often validated at component level but rarely on major component level, which is a must to allow the implementation of fully qualified technologies on aircraft level. The rear-end ground demo will provide the opportunity to test such technologies at representative scale reducing associated risk of such innovative technology, allowing successful implementation on final product.

The integrated rear end demonstrator will therefore perform mayor component manufacturing try-outs, physical tests and validates the multi-functional integration of all associated non state of art technologies and disciplines at TRL 5 and 6, as well as to consolidate the CROR safety and certification maturation. In advance to the demonstrator essential capabilities for virtual testing, new test methods (e.g. engine and blade debris impact and residual strength) and simulation methods (e.g. low to mid-vibration and vibro-acoustics propagation in conical fuselage) and means (e.g. CROR near field noise reproduction and structure coupling) and benches will be developed.

IV. High-level WBS and work-sharing

The work breakdown structure of WP1.2 is tailored to adopt all results from previous CROR propulsion system integration studies mainly achieved in Clean Sky SFWA. It will further include principle decisions to identify the most potential structural concept for a next generation aircraft, scheduled to be made before 2016. The WBS reflects the need to prepare and conduct a dedicated large-scale static and dynamic test campaign. The test article will include a full aircraft rear-end (“section 19”), including a vertical and horizontal tail plane, pylon, systems and a representative number of frames of “section 18”, representative for the pressurized part of the fuselage including the rear pressure bulk head and part of the cabin. The engine and engine loads will be
simulated by a special loads generator, the noise impact from the innovative propulsion system will be simulated with a high energy field noise generator.

A proximate work share of 30% will be taken by Airbus and relates to most of the preliminary design, part of the detailed design of the demonstrator, a significant share of the manufacturing and assembly work of the structural parts, as well as to lead the preparation, the conduct and analysis of the test. 40% of work shall be offered in significant shares for Core-Partner(s) to share the detailed design of structural components, manufacturing and assembly, as well as the preparation, conduct and analysis of the impact, static, dynamic and other tests. Research Establishments will be invited to adopt activities through Core-Partner shares or CfPs. Up to 30% of activities will go through CfPs for dedicated component developments and testing, in particular for structural shielding design, preparation of advanced test equipment, diagnostics and test methods.

V. Planning roadmap, targeted technology readiness levels

The planning roadmap is synchronized with the entry of initial deliveries from Clean Sky SFWA and SAGE, namely the conclusive availability of the CROR ground test engine results and the subsequent engine flight test bed Preliminary Design Review PDR in 2016, which will include most of the definitions required to start the preliminary design of the rear-end ground demonstrator.

With a start of the preliminary design phase of the rear end demonstrator in 2016, the PDR is planned early 2018, in line with TRL 4/5 readiness level maturation of required CROR integration mandatory technologies.

Following the Critical Design Review CDR scheduled at the end of 2018, the launch of the manufacturing and assembly activities of the rear end components for the different execution will be started, and expected to conclude by middle of 2021. At that time, first flight test results will be available as inputs for driving RED testing conditions.
The test will be performed until end 2023 with subsequent test analysis until 2023 that will feed the TRL 6 of CROR integration rear-end technologies planned early 2024.

According to this planning, main decision gate is defined in 2017, when engine ground demo test results will validate the potential of CROR engine advantage compared to other innovative propulsion alternatives, validating also the planned way forward for CROR flight test bed and rear-end ground demonstrator.

Depending on the conclusions of such gate, the scope of the project could be re-oriented to other advanced engine configurations integrated on rear-end driving to equivalent problematic such as the UHBR integration, fuselage boundary layer ingestion, multi-fan, etc.

The re-definition of rear end concept could also be considered at that time, as not hardware investments will be performed yet, envisaging optimization of rear end architecture with re-use of available developed technology, and to make use of the typical fuselage design and manufacturing principles (conical and double-curved shapes) for conventional configurations.

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VI. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

As there is no CROR engine development planned in the Engine ITD, and no specific CROR engine related system activities planned in the Systems ITD, WP1.2 will highly be dependant on a close interfacing to SFWA and SAGE in Clean Sky. The following links are of particular importance:
Large Passenger Aircraft IADP

- Platform 1, “CROR Demo Engine FTB”, WP1.1 and “Demonstration of Radical Aircraft Configurations”, WP1.6
- Platform 2, “Next generation aircraft integrated cabin-fuselage-systems demonstrators”, WP2.1
- Platform 2, “Next generation aircraft fuselage concept integration”, WP2.3
- Platform 3, “Next generation aircraft systems, cockpit and avionics”, WP3

Airframe ITD - Technology Stream A-1, “Innovative Aircraft Architecture”

- “Optimal engine integration on rear fuselage”, WP1.1
- “Open Rotor (CROR) configurations”, WP1.2
- “Novel certification processes”, WP1.4

Link with Systems ITD, with main system components and technologies (e.g. more electrical ECS) will be a firm element of the detailed work plan.

In addition, there is a mainline exchange planned with the TE and Clean Sky 2 Eco-Design work packages as described in the related chapter.

VII. Work-sharing and provisions for scope of work

The effort in this work package comprises project administration, maturation from TRL 4 to 6 (depending on rear-end demonstrator components) and test support engineering and design/manufacturing activities, component and sub-component test activities (virtual and physical), data reduction and analysis as well as hardware demonstrators. A substantial engagement of core partners and CfP partners is planned for virtually all activities.

Several rear fuselage demonstrators are to build up. For the purpose of static / impact tests (certification) a complete rear fuselage comprising pylon, T-tail representative, rear-pressure bulk head and representative S18 is required. For dynamic and fatigue test an additional rear fuselage is needed. One of the previous executions will be used for physical system installation and operability validation. Depending on prioritisation and possible show-stoppers avoiding re-use of executions for mentioned multi-testing approach, additional executions or retrofit of one of those previous executions is considered.

Depending on decision gates, budget scope of the project could be re-oriented to other advanced engine configurations.

Also depending on decision gates, a re-definition of the concept could be used for the optimisation of the rear-end conventional or wing mounted architecture to be combined with typical fuselage barrel of conical and double-curved area, for fully multi-purpose integration with the typical fuselage and cabin.
VIII. Synthesis of added-value with respect to H2020 targets

<table>
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<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
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<td>CROR Structure And System Integration</td>
<td>CO2: - 15 to -20%</td>
<td>Green lifecycle, Cost of operation, cost of production</td>
<td>Reduce dependancy on fuel price</td>
<td>2020</td>
<td>Airbus CS2 Leaders CPs (Large aero-industry, suppliers) CfP Partners (SME’s and RE’s)</td>
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6.5.4 “Validation of Scaled Flight Testing” – WP1.3

I. Relevance of the Technology for H2020

Large-scale integrated flight test demonstration is considered to be an indispensable key step of validation for a new technology to reach TRL 6. Testing at large- or even full-scale, under operational conditions, with all essential features of the technologies being integrated and working is a key mean of Research and Technology in Aeronautics to be able to address and manage the residual risks which are inherent to such complex systems in an environment of realistic ambient conditions. This is even more relevant, if the technology to be validated has a strong impact on the design and functioning of neighbouring systems and structures. If in extreme conditions a combination of complex new technologies are combined, this would probably lead to an aircraft which is “unconventional” configured and for which existing tools, knowledge, and experience on the principle interactions of these technologies in operational conditions are only partially or not available. It is obvious, that for these cases, flight testing on board of test aircraft of representative type and size can become enormously challenging and costly, if not impossible.

Scaled flight testing is a potential technology, or better “tool”, by providing the required test means not at “full-scale” but at “required scale”, going along with a very significant potential of reduction of test preparation and test time, cost, effort and risk.

Scaled flight testing do not directly contribute to Horizon 2020 targets as technology to be implemented on an aircraft but as key enabler to mature new, in particular radical technologies to TRL 6, and thus for industrial application.

The intention of this of work package is the systematic proof of scaled flight testing as viable means to mature and validate new aircraft technologies and aircraft configurations to high levels of technology readiness and the representativeness of the results for full-scale vehicles. This includes the evaluation of the reliability and quality of this mean, including the definition of a principle set of standard rules and procedures for all contributing elements as well as the quality of the equipment and measurement instrumentation. The modular design of the vehicle intended to use for the test provides the favourable opportunity of conducting related tests with different major components, such as wings, rear fuselage, engines including engine positions which clearly contribute to cost efficiency and flexibility of testing and the multi-purpose-use of the flight test vehicle.

II. Demonstration Objectives

It is planned to make use of the flight-test vehicle (named IEP) developed in the former EU collaborative research programme NACRE (FP6).

The key objectives are:

- Assessment of the perimeter and boundaries of scaled flight testing with respect to aerodynamic similarity and performance, structural- and flight dynamics.
- Design of the test plan and the associated development of the required procedures and the specification of testing conditions.
- Further development and validation of the test vehicle and supporting testing environment for the baseline configuration.
- The change to a different overall aircraft configuration.
- Demonstration of new technologies with an in-flight context.
Throughout the project technology assessments will be performed for tracking risks but also analysing strengths, weaknesses and physical limitations. The key experiences of former projects with scaled flight test vehicles will be exploited and considered.

### III. Added-value versus state-of-the-art

- In Europe research work on scaled flight testing was performed in the EU (FP6) collaborative research project NACRE. This work package considers the findings and experiences from NACRE as basis and starting point. Comprehensive technology and configuration development work using Unmanned Aerial Vehicles (UAV) is known from European military industry such as Rheinmetall Defence.
- In the US there are several on-going programs targeting the objectives of this work package.

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<td>Dynamics modeling and control beyond the normal flight envelope</td>
<td>(AirSTAR) Airborne Subscale Transport Aircraft Research</td>
<td>5.5%, dynamically scaled 757</td>
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<td>Radical configuration flight demonstration</td>
<td>X-48</td>
<td>8.5% model Blended wing-body configuration</td>
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<tr>
<td>New technology flight demonstration</td>
<td>X-57A MUTT (Multi-Utility Technology Testbed)</td>
<td>Exchangeable wings, aeroelastic control technologies for flutter suppression and gust control</td>
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### IV. High-level WBS and work-sharing

The work breakdown structure of this work package is tailored to deliver on the five main objectives outlined in paragraph 2 of this section to:

- Review, exploit and translate the principle rules of aerodynamics, structural- and flight dynamics with all relevant physical rules of similarity into a systematic context to understand for which test objectives, at which physical size, weight and for which range of parameters scaled testing can be used to acquire representative test data of high quality.
- Develop and establish a complete flight test environment (vehicle, ground equipment, data process and data link), principle rules and processes for operation and operators, to ensure an absolutely robust, reliable and safe research tool on industrial standard.
- Demonstrate the principle capability to test a novel, radical configuration with the test platform. The configuration should be derived taking into account recent findings from other WPs of CleanSky2, to prepare for WP1.6. The assessment includes designing and building new parts, flight-testing them and evaluating the results.
- Demonstrating a new technology using the platform. This could for example be a health monitoring system transmitting flight data to the ground. This includes designing test systems, performing the flight tests and evaluating the results.
In this work package, only 10% of the work share shall be taken by Airbus, with focus to implement relevant industry type, large commercial aircraft flight test rules and procedures in the key principles of scaled flight testing. As the majority of work lies clearly in the typical scope and competence of Research Establishments and Academia, the majority of work shall be dedicated approximately half and half to related Core-Partners, respectively Call for Proposal Partners.

V. Planning roadmap, targeted technology readiness levels

The planning is made according to the aim of the work package, namely to provide evidence about the viability of scaled flight testing for the validation of advanced aircraft technology, radical aircraft configurations and to make this available as complementary tool providing essential data to accomplish TRL 6. The planning roadmap starts early in the LPA-IADP Programme and shall lead to firm results in 2018.

The challenging work programme requires a straight build-up on existing results and the adoption of existing hardware, which needs to be updated to the latest state-of-the-art within 12 months time approximately. The incorporation and use of knowledge and intermediate results - as accomplished in the FP6 NACRE project - shall be envisaged and discussed with the European Commission and owners of the project foreground IPR.
A phased development, testing and improvement programme centred around two major flight test campaigns is in the heart of the programme. The plan is to adopt the modular scaled flight test vehicle from NACRE. An alternative route is to develop a scaled new vehicle representative for a large transport aircraft. The second option would lead to a 12 months extension of the programme (at least) to account for the definition, development and build phase.

VI. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

Principle results about the viability of “Scaled flight testing” will be available for other categories of vehicles with relevance for other IADPs. Based on further downselection of candidate technologies for a next generation large transport aircraft, the wing technology, the propulsion system, the overall aircraft configuration, the results of this work package should directly feed into a dedicated scaled demonstration in WP1.6.

As explained, it is planned that this work package builds on results and data achieved in previous European Funded Projects like the FP6 project “NACRE”.

The results achieved shall provide the basis for a potential first use in the LPA-IADP WP1.6 “Demonstration of Radical Aircraft Configuration”. The content of a related potential demonstrator programme depends on the selection of key technologies for a next generation short and medium range transport aircraft which will be part of the first years of the Clean Sky 2 Programme runtime. It is expected that this may be decided based on a combined major LPA-IADP review to be held at the end of 2018.

In contrary to most other work packages, this work package is not considered to deliver any direct result to the Clean Sky 2 TE and LPA Eco-Design work package.
## VII. Synthesis of added value with respect to H2020 targets

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology objectives</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Lead actors / Key Contributors</th>
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<tr>
<td>D1.3. Validation of Scaled Integrated Flight Testing</td>
<td>Potential unique enabler and testing platform for demo of advanced a/c configurations and new technologies simulating full scale aircraft conditions</td>
<td>n/a</td>
<td>Key enabler for high TRL integrated technology validation through flight test demo</td>
<td>n/a</td>
<td>2020</td>
<td>Airbus CS2 Leaders CPs (RE’s) CFP Partners (Academia, SMEs)</td>
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6.5.5 “Hybrid Laminar Flow Control Large Scale Demonstration” – WP1.4

I. Relevance of the Technology for H2020

The reduction of the aerodynamic drag of large transport aircraft by application of laminar technology is one of the very few remaining viable opportunities that can offer a potential of a double digit decrease of specific fuel burn. For short and medium haul large transport aircraft, the Natural Laminar Flow (NLF) technology is currently pushed forward to maturity in major ground and flight test demonstrations in Clean Sky SFWA, complemented by significant R&T activities in the LUFO IV programme. When applied on wings only, the expected fuel saving is 6-7%.

Due to the higher Reynolds and Mach numbers of larger and faster long range aircraft, a significant reduction of the aerodynamic drag through maintaining laminarity at large areas of the airframe surface cannot be achieved by NLF technology, but requires so-called “Hybrid Laminar Flow Control” (HLFC). With this technology, laminar-turbulent transition is delayed by the application of suction at the leading edge of the wing, the Vertical Tail Plane (VTP) or fin, the Horizontal Tail Plane (HTP), or the nacelles of an aircraft. Applied to the wings of a long range aircraft, the HLFC technology has the potential to decrease the drag of the aircraft by 7-9% which is closely corresponding to the fuel consumption reduction potential of the aircraft per mission.

II. Demonstration Objectives

The significant drag reduction potential of the HLFC technology was addressed in a number of large R&T programmes in the US and in Europe for more than two decades ago. In 2011 Boeing revealed flight test pictures with a HLFC system applied on the fin of the B787-8 and also advertising this HLFC system as aerodynamic enhancement package for the B787 evolution. Despite this pre-serial example by Boeing and even though the physics and the technical principles are well understood, no “industrial” technology solution could be developed so far to materialize the aerodynamic potential, while keeping the complexity and weight of the required systems low.

Furthermore, the effort and cost to manufacture, operate and maintain these systems need to be brought down to an acceptable level. Boosted by the recent progress to mature the NLF technology for short range large transport aircraft, there is a significant spill-over effect of knowledge and technologies for a potential adoption of to HLFC. In addition, a set of new technologies in virtually all areas of material processing, manufacturing and automation in combination with new materials open the door to develop industrially viable solutions for HLFC.

Based on the results of the FP7 L2 Project “AFLoNext”, in which the development and the first operational experience with advanced HLFC technology will be acquired, the demonstration objectives in this work package are as follows:

- Collect long-term operational experience with HLFC technology based on the “simplified HLFC concept” with regard to structure and systems architecture (HLFC technology applied on fin).
- Transfer all learnings from AFLoNext HLFC wing ground-based demonstrator and HLFC fin experience into a large ground based HLFC wing application pre-flight test demonstration.

The major steps to complete for the first topic (HLFC technology applied on fin) are:

- Adoption of the results of AFLoNext at TRL 4, TRL 5 for the HLFC Airbus A320 test fin.
- Development and manufacturing of an improved HLFC fin-demonstrator for long-term in-service operational use.
- Definition of certification processes and rules for HLFC based aircraft components together with authorities and operators / airlines.
- HLFC-fin long-term in-service demonstration (~1 year) with a commercial operator.
- Interface with the Airframe-ITD TS-A2 WP2.2 and WP2.4 to exchange / bring in major milestone results of “Extended Laminarity” technologies.

The major steps for the second topic (HLFC wing application) are:

- Transfer of learning from AFloNext HLFC wing leading edge structure demonstrator.
- Development of flight test concepts for existing long range aircraft (A340 with BLADE wing modified; glove on A340; new outer wing on A330, etc.) and down-selection of most useful concept.
- Development of wing ice protection and Krueger kinematic system for application in large-scale pre-flight ground demonstrator.
- Design, build and test of a large-scale pre-flight ground demonstrator to bring the HLFC technology to TRL5. The principle setup may be similar to the BLADE NLF-wing project within the Clean Sky demonstrator SFWA but focus will be here on the leading edge integration. The major objective will be not only on the aerodynamic efficiency demonstration but even more on the simplified structure and manufacturing concept acceptable for 3D wing surfaces. The manufacturing process chosen has to be aligned and demonstrated with future low cost production processes in an industrial environment.

Overall, the work package will include two major flight test demonstrators and complementary ground-based demonstrators, which are complemented by research and industry-type wind tunnel tests. The detailed definitions of these demonstrations will be part of the work programme.

III. Added-value versus state-of-the-art

In 2011, a simplified suction system was tested on the VTP of a Boeing B787. However, in Europe the technology is still far away from industrial maturity. The state-of-the-art for large transport aircraft is the “turbulent flow” wing design.

IV. High-level WBS and work-sharing

The high level WBS of this work package is tailored to address the main objectives of the project in individual “level 3” work packages, as explained in the paragraph 2. Due the expected size, and complexity of the activities, and also to provide the flexibility required to prepare and conduct major flight demonstrations, the HLFC flight test demonstrator as well as the supporting ground-based component demonstrators are hosted in individual work packages.
V. Planning roadmap, targeted technology readiness levels

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<td>1 Adoption and review of HLFC techno status</td>
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<td>3 Dev. &amp; manuf. of a HLFC full scale F/T Fin</td>
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<td>5 Fin certification &amp; demonstration in-service</td>
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<td>6 Development of a 3-D HLFC industrial concept</td>
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<td>7 Non-spec. design of LPA HLFC wing</td>
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<td>8 Manuf., assy. &amp; test HLFC wing component demos</td>
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<td>10 Complementary WTT tests, rig tests, CFD</td>
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<td>11 Spec. design, manuf. of HLFC pre flight demo</td>
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<td>12 HLFC large scale pre-flight demo</td>
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<td>13 Analysis of data &amp; results</td>
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<td>TRL of HLFC technology concept</td>
<td>Applied on VTP</td>
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<td>Applied on wing</td>
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The roadmap of this work package is essentially built on the maturation of the HLFC concept for a fin and for a HLFC application on wing of large transport aircraft. The representative integrated demonstrators are in-service large passenger aircrafts for HLFC fin, respectively the HLFC wing large scale pre-flight demonstrator, complementary component demonstrators, Computational Fluid Dynamic (CFD) work and Wind Tunnel tests.

As the activities in this work package depend on the results accomplished in other relevant R&T programs, the expected start is in the beginning of 2015. Expected end of the programme in the work package is summer 2023.
VI. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

Substantial exchange is expected with Airframe ITD WP A-2.2 “NLF Smart Integrated Wing” and WP A-2.4 “Extended Laminarity”. Note that overlap in the activities is expected between large transport aircraft and business jets. Depending on the intermediate results to be reviewed and the subsequent definition of the large demonstrators, a co-operation on well-defined subjects in the related demonstrators is expected. Major inputs are expected from the results in Clean Sky SFWA and the FP7 AFLoNext Project as well as from currently running Lufo IV projects addressing laminar flow technology. In addition, there is a mainline exchange planned with the TE and Clean Sky 2 Eco-Design work packages as described in the related chapter.

VII. Synthesis of added value with respect to H2020 targets

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Lead actors / Key Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1.4A: HLFC applied on fin flight test demonstrator</td>
<td>Aerodynamic drag reduction through laminar flow for LPA at cruise conditions</td>
<td>CO2: -7 to 9%</td>
<td>Green operation, cost of operation</td>
<td>Reduce dependency on fuel price</td>
<td>2020</td>
<td>Airbus/ Dassault CS2 leaders CPs (RE’s, large aero industry) CfP partners (SME’s, RE’s, Academia)</td>
</tr>
<tr>
<td>D1.4B: HLFC wing large-scale pre-flight demonstrator</td>
<td>Aerodynamic drag reduction through laminar flow for LPA at cruise conditions</td>
<td>CO2: -7 to 9%</td>
<td>Green operation, cost of operation, cost of production</td>
<td>Reduce dependency on fuel price</td>
<td>2020</td>
<td>Airbus/ Dassault CS2 leaders CPs (large industries structure and systems, RE’s) CfP partners (SME’s, RE’s Academia)</td>
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</table>
6.5.6 “Applied Technologies for Enhanced Aircraft Performance” – WP1.5

I. Relevance of the Technology for H2020

The desire for more ecologic and more economic turbofan engines in civil aviation leads to increasing “Bypass Ratios” (BPR) and lower “Fan Pressure Ratios” (FPR), predicting up to double-digit reduction (relative to year 2014 baseline) in fuel consumption and thus COx and NOx emissions.

Associated with both features are larger fan diameters along with larger engine nacelles, typical for “Very High Bypass Ratio” (VHBR), “Ultra High Bypass Ratio” (UHBR) or “Geared TurboFan” (GTF) engines. With increasing nacelle size the engine integration under the wing of current, re-engined aircraft under development (e.g. A320 NEO) is already challenging but becomes even more when novel aircraft configurations are considered introducing even larger engine sizes.

The design challenge of integrating such engine types to the wing originates not only by the mechanical and spatial integration but also by the very close aerodynamic interaction of both major components (engine, wing) to each other, s. Figure 6.7a.

This close interaction requires a multi-disciplinary conceptual design from the beginning on, much more than today, in which both major components are consistently and equally designed to each other so that the targeted net benefit in terms of overall aircraft level efficiency is assured. The underlying design process will enhance a thorough understanding of the key design parameters, its sensitivities and the interrelations to each other, which really enables to design to a coalescence of wing and power-plant system. This is seen as an important asset to maintain the European leadership in innovative aircraft design.

Beside an appropriate design approach, enabling technologies are needed to realize the physical wing/engine integration by providing answers to technical challenges resulting from the close coupling of engine to wing and therefore the close vicinity and interaction (flow, loads, thermal impact, etc.) of both major components to each other. This requires for example to master highly 3-dimensional flows accompanied by partly separated flow areas on wing, any potential clashes between moving and fixed structural parts (high-lift elements, thrust reverser, fixed wing, etc.), an increased thermal load impact on structure, load carry-over effects between engine and wing, noise problems (airframe-, engine-, structural noise), etc.
In many cases, conventional design means are often not sufficient to cope with the technical challenges described above. However, state-of-the art research shows that highly promising technical solutions for flow-, load- and noise-control could be, if they are successfully designed and applied, the crucial physical enablers so that the expected net benefit of the targeted wing/engine integration scenario will be realized.

**Novel wing design** making use of advanced materials, exploiting its mechanical properties for improved structural design and making use of complementary manufacturing principles promise a great leap forward in aerodynamic efficiency and thus fuel reduction. The improved environmental and socio-ecologic compatibility of future aircraft and at the same time the compliance with the more and more densely used air space requires wings with **on-demand outer wing load distributions, highly adaptable**, for improved aircraft performance and aircraft separation capabilities thus enabling closer aircraft-to-aircraft separation in cruise and during take-off and approach.

II. **Demonstration Objectives**

There are two major objectives for WP1.5: The first major objective of the work package as a whole is the development of technologies which enable the physical integration of large-sized, ultra-efficient turbofan engines to the wing in a symbiotic manner such that the overall performance benefit of the whole configuration (wing/engine) is maximised. The second major objective is to perform a multi-disciplinary wing/engine conceptual design with these enabling technologies in the loop. In fact, both major activity lines shall happen at the same time in a complementary manner so that the design steps and decisions taken in both activity lines are well aligned to each other and the mutual benefits are maximised.

Furthermore, WP1.5 views itself as a catalyst work package which interacts with many other work packages in LPA and the ITDs in order to concentrate and relay the knowledge gained from novel power-plant system design activities and its integration to the wing, preparing therefore the design basis for a flight test demonstration of a novel UHBR-propulsion system installed on an existing flight test aircraft to be performed in WP1.6. More details to this under chapter IV High-level WBS and work sharing.

WP1.5 is centred around a design exercise for a wing featuring a VHBR/UHBR engine optimised for operation at high sub-sonic Mach-No., to be performed in WP1.5.1, s. Figure 6.7a. The target configuration for this design exercise is the Large Passenger Aircraft (Single Aisle or Long-Range aircraft). The scope covers major design aspects for a wing concept which tolerates a VHBR/UHBR propulsion system integration considering the specifics coming along with the associated pylon/nacelle layout and a suitable high-lift/movable design strategy.

The enabling technologies are clustered regarding their nature and target application and will be developed in the respective sub-work packages as follows (s. also Figure 6.7c):

- Power plant 2025 integration technologies in WP1.5.2
- Flow control for UHBR integration in WP1.5.3
- Technologies for loads and noise control in WP1.5.4

Although the target configuration for WP1.5 is the Large Passenger Aircraft there are many similarities with business jet design objectives for instance the high sub-sonic design Mach-No. or the targeted power-plant systems. WP1.5 offers therefore the opportunity to exploit the area of enabling technologies for business jet applications too, aiming to maximise the synergies between both aircraft configurations.

WP1.5.4 has the objective to develop novel airborne sensor technologies. Commercial aircraft performance with regard to fuel burn and associated emissions as well as with regard to operations in more and more densely utilized air space can be improved by allowing multiple aircraft to operate closer than it is feasible today. Today's
limitations stem from the need to assure collision avoidance and wake turbulence separations, both of which, in controlled airspace, are provided by Air Traffic Control (ATC) supported by diverse technologies. New commercial aircraft sensor technologies and novel applications of existing airborne sensor technologies can enable reduced separations and even unlock the opportunity to gain direct fuel burn reductions from operating aircraft at precisely-controlled, energy-saving relative positions. These sensors need to be able to detect and potentially characterize the relative positions of other aircraft as well as their wake turbulence. Unless required solely for calibration, these sensors will be subject to the high overall performance requirements typical for commercial aircraft sensors (reliability, accuracy, maintainability, cost, environmental performance, aircraft integration constraints etc.). Candidate technologies include laser, radar and infra-red but also classical commercial aircraft sensors like inertial and air data, albeit to new, specific requirements, for example with regard to integration.

In more detail, each sub-work package has the following demonstration objectives:

The intention of WP1.5.1 is to make a basic design but which is characterised by the fact that “all” influential design parameter are identified and considered in a comprehensive manner. It is clearly not the idea to make heavy design optimisation loops on a basis which doesn’t show the full design situation. The expected high challenges of integrating such engine sizes to wing requires the exploitation of the design space beyond the conventional approach by adopting enabling technologies as a key design parameter from the beginning on. It is planned that the inner design exercise (full design situation) is performed by Airbus using the existing and validated aerodynamic wing/power-plant design chain with the according tool suites. Partners are contributing with essential technology developments and associated design targets and constraints.

As mentioned above, WP1.5, here in particular WP1.5.1 and WP1.5.2 shall also provide the design environment to define the preferred aircraft/wing/engine architecture to prepare the flight test demonstration of a novel UHBR propulsion system installed on an existing flight test aircraft to be performed in WP1.6. The underlying technology strategy for this UHBR propulsion system targets an application on serial aircraft which enter into service 2025. The activities in WP1.5.1 and WP1.5.2 shall be done in close interaction with the relevant ITD Engine work packages and the WP1.6, s. also chapter IV High-level WBS and work sharing.

The objective of WP1.5.2 is defining and developing technologies which enable the physical integration of large-sized power-plant systems to the wing. Particular emphasize is put on mastering the physical effects resulting from the close-coupling of the engine to the wing and ground such as clearance heights, aero-acoustic effects, inflow conditions to the engine and flow circulation around the engine, thrust-drag decomposition, thermal loading on structure, etc. The resulting fluid-mechanical effects between power-plant system and wing will be covered by WP1.5.3.

The demonstration objectives for WP1.5.3 are a direct result of the need to master the complexity of the flow situation on wing coming along with the integration of large-sized power-plant systems to the wing. In summary, the flow situation is driven by two aspects:

Firstly, at high angles of attack and low speeds current conventional aircraft with under-wing mounted engines are susceptible to local flow separation in the region inboard of the wing/pylon junction. This separation is triggered by interfering vortices originating from the engine nacelle, the slat ends etc. Secondly, with larger engine nacelles it becomes more difficult to ensure sufficient clearance between the nacelle and the runway for the aircraft on ground. To evade longer landing gear struts causing weight and space penalties as well as an increased level of landing gear noise, the engine is closer coupled to the wing. The close coupling requires slat-cut-outs in the region of the wing/pylon junction in order to avoid clashes of the deployed slat with the nacelle. These slat-cut-outs further exacerbate the risk of the aforementioned separation. Possible consequences are the degradation of the high lift performance and the reduction of maximum lift in which the
maximum lift coefficient for the landing configuration and the lift-over-drag ratio for the take-off configuration are directly related to the achievable payload or flight range.

In current aircraft, the maximum lift is significantly improved with strakes mounted on the inboard and also sometimes on the outboard side of the engine nacelle. In addition to those passive means some aircraft incorporate and/or novel mechanical leading edge devices that fill the slat-cut-out and reduce the aerodynamic performance degradation due to engine integration. On the one hand, strakes cause a frictional drag penalty since they are also present at high speed conditions when unneeded and additional deployable mechanical leading edge devices, such as Krüger flaps, introduce further complexity and weight. On the other hand their aerodynamic effects are limited and for modern VHBR/UHBR engines the problem of possible local flow separation persists leaving further space for optimizing the high-lift performance.

For achieving the maximal overall aircraft performance benefit of UHBR engines it is therefore intended to further exploit and apply the potential of flow control technologies, in a consistent follow-up of former or running EU projects like AVERT and AFLoNext (“Active Flow- Loads & Noise control on next generation wing”). With respect to AFLoNext, the WP1.5.3 shall be directly engage with it and complement the design and test work. The key demonstration objective of WP1.5.3 is the following:

Flight test an integrated solution of advanced flow control means installed at the engine/wing junction while demonstrating the high-lift performance increase suitable for enabling future UHBR engines installed under the wing.

- Exploitation of the AFLoNext TRL4 large ground demonstration, to build upon this know-how to reach TRL6 in Clean Sky 2 in an efficient and robust manner with manageable risks, s. Figure6.7b. This covers all disciplines being active in AFLoNext: aerodynamics, structure, systems addressing the UHBR configuration and flow control hardware developments and testing.
- Adoption of results from the parallel running AFLoNext project to derive flow control technologies for a high Reynolds number wind-tunnel validation to make a multidisciplinary proof of concept at fully realistic Reynolds numbers and flow Mach numbers, see Fig.6.7b. This is an essential technology brick, since separation effects are strongly dominated by Reynolds number effects and actuator control authority by flow Mach No./blowing ratio.
- Engage with the flow control actuator development and selection in AFLoNext. Possible actuator solutions for Clean Sky 2 are:-: “pulsed air blowing” with or without net mass flux or “continuous (tangential) blowing”.
- Design and development of the flow control actuators/hardware at aircraft scale, which is suitable for flight test integration and associated wing leading edge / pylon/nacelle modifications.
- Full-scale ground system-mock-up as preparatory step for flight test (hardware-in-the-loop), account for engine specific characteristics (hot bleed-air, electric generators etc.) and aircraft interfaces.
- Close interaction with Airframe-ITD and Systems-ITD, where innovative component technologies will be developed and tested, such as the design of advanced, reliable, robust and efficient flow control hardware.
- Delivery of results and conclusions of all pre-tests (full-scale ground tests, large-scale wind-tunnel tests) in order to de-risk and get approval for flight test with aircraft equipped with active flow control.
- Investigation of the opportunity to integrate this local flow control device into conventional flight test aircraft and also into future serial aircraft wing design. This in close context with WP1.5.1 and WP1.6.
- Flight testing of flow control applied on engine/wing/pylon interface will be the first implementation of a leading edge flow control system on a commercial aircraft. Even though this is likely to take place on a Single Aisle aircraft it is also envisaged to extrapolate the data to Long-Range aircraft application.
WP1.5.4 covers the development of technologies applied on airframe controlling resulting loads and noise effects due to the presence of large-sized, ultra-efficient turbofan engines in an aircraft configuration (structure vibrations and noise, etc.), in particular for rear-mounted engine configurations. Regarding this point a close link to WP1.2 shall be provided. Also within the scope of this sub-work package are investigations about any emerging shape-design requirements for the airframe and ways to control it due to the substantial geometrical impact of the large-sized engines on an aircraft configuration. Disregarding such design aspects like the influence of pressure gradients, shocks, tangency discontinuities and other obstacles on airframe could quickly produce considerable drawbacks in terms of increased overall aircraft drag and weight. For the purpose of applying the acquired knowledge of WP1.5.4 for future aircraft configurations, a close link to WP1.6 will be provided, s. also chapter IV High-level WBS and work sharing.

III. Added-value versus state-of-the-art

This work package shall provide a unique environment to develop and integrating enabling technologies in the design process for the benefit of significant aircraft performance improvement. The value-add of this strategy, beyond the state-of-the-art, is based on the fact that the technologies are from the beginning on embedded in the real aircraft design process, with a clear performance target and a tangible application demand. A further novelty is the set-up of an according multi-disciplinary design process fully considering these technologies as valuable means in the complete design space from the beginning on. The enabling technologies are no longer pure add-on provisions which are designed to mitigate a problem occurring after design freeze during operation but being rather inherent parts of an aircraft design. Through this, new design opportunities shall be offered, like the possibility to integrate ultra-efficient engines of large sizes to the airframe, either on re-engined current aircraft or future complete new aircraft designs. This opportunity in particular is seen as a “door opener” to an aircraft-design space which shall offer further aircraft performance improvement beyond the pure engine improvement potential, which already predicts up to double-digit reduction (relative to year 2014 baseline) in fuel consumption and thus COx and NOx emissions. In context to this, the flight test validation of the local flow control technology on the leading edge is the first in commercial aviation history and promises great knowledge gain for the European aviation community.
The set-up of WP1.5, in which all activities are well aligned to the overall objective of realizing the integration of ultra-efficient engines of large sizes to airframe, reviews all facets of the design process. This clearly supports the robustness of the design solutions which in turn reduces the Recurrent Costs (RC) and Non-Recurrent Costs (NRC) of an aircraft.

IV. High-level WBS and work-sharing

The set-up of the WBS accounts for the overall targets of this work package in combination with the definition of explicit demonstration objectives, as outlined in the previous chapters. The WBS may be modified according to the actual needs of the LPA-IADP Programme.

![Figure 6.7c – WP1.5. Principle Work Breakdown Structure (WBS)](image)

The Airbus work share in this work package will be close to 14%, other Clean Sky 2 launching industries are expected to take up to 26% of the work shares, Core Partners (CP) will be invited to take up to 30% of the work shares. Due to the temporarily limited activities related to explicit technical subjects, Call-for-Proposal (CfP) Partners will be invited to take at least 30% of the activities.
V. Planning roadmap, targeted technology readiness levels

The planning roadmap, s. Figure 6.7d, shows the provisional high-level schedule marks for the envisioned activities and demonstrations “knowledge base UHBR/wing integration on LPA”, “powerplant 2025 integration technologies”, “flow control for UHBR integration” and “technologies for loads and noise control”. The work package shall ramp-up immediately after a successful re-evaluation and implementation in the Joint Technical Proposal (JTP) and Work Plan 2014/2015 of Clean Sky 2.

WP1.5 is scheduled to continue through the entire runtime of the Clean Sky 2 Programme with a foreseen operational start in January 2015. The typical range of maturity levels developed for the different technologies is between TRL3 to TRL6.

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<tr>
<td>1 Program Plan, Definition of demonstration</td>
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<tr>
<td>2 Knowledge Base UHBR/Wing Integration on LPA</td>
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<tr>
<td>3 Powerplant 2025 Integration Technologies</td>
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<tr>
<td>4 Flow Control for UHBR Integration</td>
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<td>5 Novel Airborne Sensor Technologies</td>
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<td>6 Technologies for Loads and Noise Control</td>
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Figure 6.7d – WP1.5, planning roadmap, targeted TRL levels

VI. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

Within Platform 1, WP1.5.1 and WP1.5.2 strongly interact with WP1.6 exchanging and exploiting knowledge gained and deliveries achieved from novel power-plant system design activities and its integration to the wing, thus preparing also the design basis for a flight test demonstration of a novel UHBR-propulsion system in WP1.6.

WP1.5.2 closely communicates with ITD Engines, WP6 to receive input about UHBR engine technology development status.

WP1.5.3 predominantly builds on flow control technology developments achieved in AFloNext where for single-lane actuated pulsed-air blowing with and without net air mass flux an industrial proof-of-concept is given within large-scale WTTs. Multi-lane, closed-loop and other innovative but less mature flow control technologies will be fed into WP153 from the ITD Airframe, TS-B, WP1.4 once technological effectiveness has been proven. With the same ITD Airframe workpackage an intensive knowledge and expertise transfer is envisioned. Further inputs will be received from former or running research projects like AVERT, Eurolift 2 etc.
Within platform 1, WP1.5.4 interacts with WP1.2 regarding rear-end design and testing.

In general, one major goal for project lead is to maximize the interrelation and benefits between the WPs and also actively identify any potential for joint activities with ECO design and Technology Evaluator (TE).

**VII. Budget provisions**

The total effort for the full-scope of activities, including the Clean Sky 2 members, Core-Partners, CfP-Partners and activities through Call-for-Tender will be 35.8 M€ gross (i.e. 17.9 M€ EU funding required).

**VIII. Synthesis of added value with respect to H2020 targets**

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Lead Actors/Key Contributors</th>
<th>ROM EC funding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D1.5 Applied Technologies for enhanced Aircraft Performance</strong></td>
<td>Advanced technologies for flow-, load-, noise control enabling UHBR integration. Extended design space for game-changing configurations</td>
<td>NOx, CO₂: 10% or even more Lower community impact</td>
<td>Maintaining the European leadership in innovative aircraft design.</td>
<td>Reduce dependency on fuel price</td>
<td>2023</td>
<td>Airbus CS2 Leaders CPs (systems industry, RE’s) CfP Partners (SME systems, equipment, RE’s, Academia)</td>
<td>17.9 M€</td>
</tr>
</tbody>
</table>
6.5.7 “Demonstration of Radical Aircraft Configurations” – WP1.6

I. Relevance of the Technology for H2020

It is the strong understanding in the community of the large commercial aircraft industry that the introduction of step-changing technologies and advanced aircraft configurations being beyond the state-of-the-art requires as an absolute “must-have” delivery an intensive and reliable phase of testing at representative scale and operational conditions. Many of these innovations with high potential for overall efficiency improvement and a highly favourable environmental impact require a significant modification of the aircraft configuration, which in turn entails tremendous challenges even for large demonstrator flight testing on existing conventional test aircraft.

The most recent wave of advanced technologies being under development for a potential integration in the next generation aircraft will most likely lead to an unprecedented need for large-scale flight testing. This also requires a level of modification which is very demanding in terms of cost, effort and technical realization. Thus, large-scale flight demonstration for a combination of new technologies may even be impossible with available test vehicles.

II. Demonstration Objectives

The intention of this work package is therefore to develop advanced aircraft concepts based upon a design strategy targeting a perfect synthesis between innovative airframe concepts and the enabling or associated technology architecture plus its comprising individual technologies. It is the objective that through such a development approach the next generation of large short- and medium-range transport aircraft will directly benefit from this. Compared to other aircraft sectors (Regional, Small, Rotorcraft) other technologies are required, so the need for a dedicated demonstration is seen. This and the intention to integrate technologies from an aircraft point of view should prevent the duplication with other planned CleanSky activities.

To facilitate the development of all-new airframe components and technologies with their associated validation and verification needs, the existing testing strategies and testing processes have to be reviewed and aligned to these new requirements. The current understanding is that without an adequate testing strategy and a consistent demonstrator approach, all-new technologies for large transport aircraft cannot make the way into application because the inherent risks are too high, mainly with respect to safe testing operation and due to a strong need for flexibility and modularity - to be adaptable for rapid changes in testing objectives and testing conditions. The plan is that many of the promising airframe concepts and components, the technologies as well as the suitable testing platforms will be firmly selected in the course of the first four years of Clean Sky 2. Based on the progress and the results of the other work packages in the IADPs of LPA and depending on the choice of technologies to be matured towards TRL 6, a careful review of the demonstration requirements versus the demonstrator options will lead to the definition of a productive testing strategy and the means exactly suited to the required demonstration objectives. Regarding the testing platform, the aforesaid includes in particular the option of making use of a scaled demonstrator developed in WP 1.3.

An example for promising technology architecture and its comprising technologies for hybrid propulsion, Fig. 6.8 shows a novel hybrid power chain with a substantial potential for efficiency improvement with regard to environmental compatibility.
III. Added value versus state-of-the-art

For the benefit of next generation large short- and medium-range transport aircraft, this work package shall deliver a set of advanced aircraft concepts with the associated technology architectures, including propulsion, which are developed and matured by means of new, well-suited testing strategies and testing processes. In particular for the latter, the state of the art does not provide this capability, neither regarding suitable testing platforms nor for corresponding testing processes and execution.

The work package opens a new design and validation space offering through this a set of efficiently developed (time, cost) and validated airframe concepts and associated technologies for advanced aircraft configurations. This is seen as the core value-add of the deliverables produced in this work package in order to overcome the threshold to full game-changing aircraft design. Further added value is given through many interrelations with other work packages in LPA IADP and also ITDs, either through development partnerships or through customer/provider relationships for emerging technologies in order to maximize mutual benefits, multi-purpose use and exploitation of the developments made.

In the US, there are different activities targeting the demonstration of radical configurations. Three industry proposals are looking at different designs for a ‘STV’ (Scaled Testbed Vehicle), the NASA ‘NTV’ proposes a suitably modified airframe. Additional studies look at novel energy sources and their impact on configurations.

IV. High-level WBS and work-sharing

The structure of this work package provides a scheme that enables at the same time and strongly synchronized to each other, the definition, design and development of promising airframe concepts and associated technologies as well as the required testing processes and environment.

The assumption is that best candidate technologies are mature at TRL 5 respectively TRL 4 towards the end of 2018 as a result of preceding research and technology carried out in Clean Sky 2 in the ITDs, or emerging from other component/technology demonstrations in the LPA-IADP, as well as in WP1.6 itself. Complementary technologies may be embarked from other research and development programmes. Including the conceptual
phase, the time required to deploy, prepare, conduct and analyse the programme is estimated at approximately 120 months.

The demonstration will implement a step-wise approach for de-risking. Suitable components for the hybrid energy concept also sourced from outside the aviation sector, are integrated into concept demonstrators. These concepts or particular technologies associated to them can be demonstrated in flight for certain aspects either with the Scaled Flight Test vehicle from WP1.3 or by means of the testing platforms deployed in WP 1.5. Fig. 6.9 shows the principle Work Breakdown Structure (WBS) of work package WP 1.6.

![Figure 6.11 – WP1.6 Principle Work Breakdown Structure (WBS)](image)

The activities in this work package will lead up to the end of 2018 decision including the demonstration of novel propulsion concepts. The overall aircraft architecture will be a result of the opened design space, i.e. of the hybrid propulsion architecture. Within WP 1.6.1/2 basically four activities will converge to a validated concept:

a) Definition of the optimal hybrid propulsion architecture with respect to flight mission profiles, based on synergies and opportunities. An investigation of the interactions and limitations of radical aircraft configurations and of projected hybrid energy technologies shall lead to a sound concept. Fig. 6.10 shows schematically the comprising technologies of hybrid propulsion architecture.
b) Based on the conceived architecture, definition and layout of the best suited crucial components and sub-systems of the hybrid power train, namely in the areas of energy storage, motors, power distribution, power control, specific aircraft interfaces.

c) Looking at the defined systems scope, advanced technology bricks like Boundary Layer Ingestion (BLI) or Distributed Propulsion (DP) will be additionally needed in order to raise overall efficiency. The combination of a hybrid propulsion chain with advanced technology bricks will provide new design parameters to open the design space for overall aircraft design, and finally this will result in design requirements and constraints for radical aircraft configurations. The appropriate architecture with the associated technology combination, compatible to the defined aircraft architecture, has to be selected to enable the validation of an end-to-end architecture.

d) Necessary hardware demonstration on systems level: Build and operate a hybrid power bench to test single components as well as the integrated power chain to confirm overall aircraft design assumptions and to validate concept feasibility, leading to the required input for systems design for flight test.
A modular approach for the hardware demonstration in WP1.6.2 is proposed, to enable the engagement of necessary partners.

<table>
<thead>
<tr>
<th>Module</th>
<th>Partner</th>
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<tbody>
<tr>
<td>Overall integration</td>
<td>Airbus</td>
</tr>
<tr>
<td>Propulsor (fan)</td>
<td>Engine manufacturer</td>
</tr>
<tr>
<td>Electric drive</td>
<td>Partner outside aviation</td>
</tr>
<tr>
<td>Electric distribution</td>
<td>Systems supplier</td>
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<td>...</td>
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In addition, alternative propulsion concepts, such as UHBR, are followed up.

To validate all assumptions, hardware demonstration is as well required on aircraft configuration level: WP 1.6.4 shall therefore focus on converging the validated concepts and systems under the roof of an optimized and advanced overall aircraft design, including the application of achievements in WP 1.3, to feed the flight test vehicle design.

A review and potential update of the WBS is foreseen end 2018 based on the results of WP1.3.

WP 1.3 is seen as an important de-risking step for WP 1.6. If the capability is demonstrated successfully, it would provide a demonstration mean between ground tests and flight tests, in respect of effort and precision. Especially dynamic behaviour and extreme flight requirements could be demonstrated. The risk and cost of testing a new configuration would be lower than for a full-scale manned flight test.

At the decision gate in 2018 it is expected that the following elements for flight demonstration are fully known in their capability:

- Scaled Flight Testing
- Use of smaller, manned test bed with larger modifications, but demonstrating technologies for Large Passenger Aircraft
- Modification of larger aircraft, but in a limited scale

It is expected that a combination of these test means is selected. Also, appropriate ground tests such as wind tunnel tests will be part of the overall demonstration strategy.

Fig. 6.11 shows part of the V&V strategy for the WP:
The WP consists of two main parts, with a major decision gate at 2018. Leading up to this decision gate is shown the development process for the Hybrid Electric propulsion system, to the left side. Not detailed here, a similar, parallel process will be used to develop the new configuration itself.

At the decision gate inputs from other Clean Sky 2 activities are fed in. The development process for the configuration demonstration is then shown to the left. The process is only shown for one platform, but this could be parallel activities on different platforms (scaled, full scale); also other configurations may be tested at different points in time.

Airbus is expected to take on the leading role in WP1.6. If an Airbus test aircraft is used as flight-test vehicle, in collaboration with WP 1.5, Airbus’ work share is expected to reach 40%. Instead, if a scaled vehicle is used, the Airbus share is expected to be below 20%. Long-term work shares shall be offered to core members at a level of 30-40%, depending on the vehicle used, CfP-Partners will be invited to contribute at a level of between 20-50% of the R&T activities in the work programme.
V. Planning roadmap, targeted technology readiness levels

As an overview, the milestones are listed below including the dates and explanations:

<table>
<thead>
<tr>
<th>No.</th>
<th>Milestone</th>
<th>Date</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Configuration defined</td>
<td>12</td>
<td>Alternative propulsion architecture and components defined</td>
</tr>
<tr>
<td>2</td>
<td>Techno’s selected</td>
<td>15</td>
<td>Technology bricks for alternative propulsion and radical aircraft configurations selected</td>
</tr>
<tr>
<td>G1</td>
<td>Power Bench available</td>
<td>18</td>
<td>Hybrid ground propulsion demonstrator operational</td>
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<tr>
<td>3</td>
<td>Pre-Tested</td>
<td>24</td>
<td>Ground demonstrator pre-tested</td>
</tr>
<tr>
<td>4</td>
<td>Fully Tested</td>
<td>36</td>
<td>Ground demonstrator tests completed</td>
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<tr>
<td>x</td>
<td>Newer/Iterative System/Component Tests</td>
<td>x</td>
<td>Optional test iterations based on WP 1.3 and further design work inputs</td>
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Phase 2 - Scaled Demonstrator Development and Testing

| G2  | Architecture converged | 45 | System architecture and aircraft configuration for scaled demonstrator selected |
| 5   | Conceptual engineering review | 54 | Conceptual engineering review |
| 6   | Preliminary design review | 63 | Preliminary design review |
| 7   | Critical design review | 69 | Critical design review |
| G3  | All major demo vehicle components on dock | 75 | Components manufactured and ready for assembly |
| G4  | Demo Vehicle complete | 87 | Demonstrator ready for ground test/roll-out |
| 8   | First Flight | 92 | First flight |
| 9   | Test Report | 98 | Flight test report available |
| 10  | Final Report | 100 | Overall evaluation report available |

Phase 3 - Testbed Components

| 11  | Concept Ready | 0 | Concept decided |
| 12  | PDR | 9 | Preliminary design review |
| 13  | CDR | 21 | Critical design review |
| G5  | Demonstrator Ready | 30 | Demonstrator available for ground testing |
| 14  | First Flight | 42 | First flight |
| 15  | Report | 57 | Final Test Report |

VI. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

WP1.6 will connect with many Clean Sky 2 LPA IADP and ITDs work packages to be able to adopt all best candidate technologies of sufficient maturity for potential combination in an advanced future generation vehicle. This explicitly includes combinations of technologies that require a “radical” configuration of large transport aircraft.
As for all other demonstrators, there is a mainline exchange planned with the TE and Clean Sky 2 Eco-Design work packages to provide relevant results of the integrated flight-tests as described in the related chapter.

In addition to Clean Sky work, it is tried to use national funded projects at lower TRL level to feed this project. For the Hybrid Propulsion demonstration, the modular set-up gives the opportunity to develop components which then can become beneficial for the integrated demonstration.

VII. Synthesis of added-value with respect to H2020 targets

<table>
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<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Lead Actors / Key Contributors</th>
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<tr>
<td>D1.6. Demonstration of Advanced Short-Medium Range Aircraft Configuration</td>
<td>Demo of a target a/c configuration with combinations of disruptive technologies</td>
<td>CO2: -25 to -35%</td>
<td>Green operation, cost of operation, cost of production</td>
<td>2020</td>
<td>Airbus CS2 Leaders CPs (large industry, RE´s) CFP Partners (SME´s, RE´s, Academia)</td>
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6.6 Platform 2 “Innovative Physical Integration Cabin – System – Structure”

For decades, the improvement made in the area of the fuselage main and substructure in combination with the cabin structural and system design were typically limited due to mutual interferences and contradictory requirements. The introduction of a “more” or even “all electric” aircraft architecture has major consequences for fuselage design and cabin system and physical arrangement. More recently, new technologies in this area have been developed and matured in a multidisciplinary manner but still at an individual level.

The approach of Platform 2 “Innovative Physical Integration Cabin-System-Structure” is to provide the frame for large-scale complex demonstration, as a segmented feature demonstrator or at full-size for validation and testing on the ground. The target is to validate high-potential combinations of airframe structures using advanced materials and applying innovative design principles in combination with the most advanced electrical system architecture in combination with the next generation cabin. The driver of this approach is to yield up to a double digit fuel burn reduction by substantially reducing the use of secondary energy, applying low weight systems and system architecture and to be able to cash in weight potentials in the structural design of the fuselage and the connected airframe structure.

Major lines of activities are broken up into the following work streams:

- New overall airframe architecture and new integration approaches;
- Assessment of the best material options for primary fuselage structure;
- Development of advanced manufacturing means and methods able to achieve high production rates with reduced recurring costs;
- Integration within a “future factory” vision, enabling among others: intelligent automation, ergonomic work environment, optimum human-machine interface, zero defects and flexible manufacturing lines;
- Integration of cabin/systems/structure functions, weight savings and reduced production costs;
- Modeling and multi-functional integration of breakthrough systems;
- New system architectures for more electric aircraft, integration of fuel cells, alternative energy generation, storage and management systems;
- Technology validation at virtual and physical full-scale;
- Validation of breakthrough technologies by simulation and physical test-beds.

I. Relevance of the Technology for H2020

The platform 2 technologies shall bring the additional improvement contributions needed from the fuselage perimeter to achieve the 30% CO2 reduction target compared to 2000 established by Advisory Council for Aeronautical Research in Europe (ACARE). The distribution of this overall goal down to specific weight and cost targets for each component and sub-component will depend on the trade-offs performed during the early phases of the project. This will allow an optimum allocation of targets and challenges, without over- or underpenalising from the beginning any of the potential alternatives (e.g. materials, technologies, architectures, etc.)

The interest in minimising weight is a target inherent to the aircraft industry since the early beginning of aviation history. The aircraft that have been developed recently are not an exception to this rule, since they incorporate lighter materials and more efficient systems up to the extent allowed by the state of the art. Lighter aircraft
require less fuel to perform a specific mission and therefore their potential for contributing to the ACARE vision 2020 is enormous. The ACARE 2020 vision targets among other goals, a 50% cut in carbon dioxide emissions per passenger and kilometre (which means a 50% cut in fuel consumption in the new aircraft of 2020) and an 80% cut in nitrogen oxide emissions. The need for weight reduction is therefore essential in sustaining the operation of a service that cannot be satisfied otherwise: short time, long distance transportation. However, this striving for lighter aircraft is not the only enabler of sustainable air transportation. Besides tight weight requirements, the aircraft also needs to fulfil increasingly strict safety standards issued by official certification authorities. And very importantly, it has to be a viable product able to fulfil the expectations of a highly competitive market, both from the operator’s point of view as well as from the passenger’s perception.

Underpinning the concept of product viability are the cost of production and the cost of acquisition. Without considering the engines, more than 50% of the recurring cost of manufacturing an aircraft is determined by the fuselage, the cabin and cargo equipment and the integration effort performed in the assembly of these components. The entirety of all these aspects constitutes a complex bundle that is decisive for the success of an aircraft programme. This is why all elements will be tackled altogether in an integrated way in a demonstration platform within Clean Sky 2.

Despite a subsequent change in the use of principle materials, the architectures of all large transport aircraft currently in the market are still quite close to the concept of jet aircraft developed for transonic cruise in high atmospheric level altitude in the fifties of the last century. A key feature virtually unchanged up to now is, for example, that the fuselage is developed almost independently of the cabin and cargo interior, except the positions specifications of windows and doors. Another key issue is that with state of the art impact and crash scenarios, the traditional fuselage structural concepts do lead to non-competitive weights and other constraints which are unacceptable targeting to develop a game changing next generation large transport aircraft.

II. Demonstration Objectives

The approach of the “Innovative Physical Integration Cabin-System-Structure” Platform is to provide the frame for maturation, integration and demonstration of the best candidate technologies for a next generation fuselage structure, cabin, cargo and physical systems integrated concept able to deliver up to a double digit fuel burn reduction. Improvements in terms of both performance and efficiency will be enabled through the use of multifunctional approaches and seek for synergies, whose validation will require large-scale complex demonstration.
Objective | Enabled by
--- | ---
Demonstrate the weight, RC, and lead time benefits of a disruptive approach towards fuselage architectures which integrate structure, system installation and cabin elements | ▪ Methodologies for a multidisciplinary and integrated way-of-working between the formerly separated research teams form different functions
▪ Elements and architectures which integrate formerly separated functions from structures, system installation and cabin, while keeping flexibility in design, manufacturing and airline operations
▪ Calculation methods and design principles for integrated structural, system, and cabin elements
▪ Manufacturing technologies for integrated structural, system, and cabin elements
▪ Testing technologies for integrated functional and mechanical demonstrators

### III. Added-value versus state-of-the-art

The targeted achievement of each one of the high-level enablers mentioned before will be supported by a series of developments going beyond the current state of art.

▪ **Methodologies for a multidisciplinary and integrated way-of-working between the formerly separated research teams of different functions:**
  - Accurate understanding of high integration design drivers
  - Accurate understanding of integration method drivers
  - Modelling and multi-functional integration of breakthrough systems
  - Unconventional multifunctional integration of structures with cabin and with systems
  - Effective new algorithms for assisted electrical routing
  - Advanced methodologies for wire sizing
  - Innovative electrical networks (power supply, data distribution and grounding/bonding)
  - Composites used as an enabler for new structural and functional solutions

▪ **Elements and architectures which integrate formerly separated functions from structures, system installation and cabin, while keeping flexibility in design, manufacturing and airline operations:**
  - Assessment of the best material options for primary fuselage structure
  - New overall airframe architecture and new integration approaches
  - New system architectures, integration of fuel cells, alternative energy generation, storage and management systems
  - Integrated cabin/systems/structure functions for weight savings and reduced production costs
  - Optimised multifunctional integration (e.g. load carrying cabin monuments, pre-equipped fuselage shells and floor grids, etc.)
  - Composite materials with low dielectric constant resins able to reduce the penalties coming from the integration of the electrical system network
- Low cost structures manufacturing through minimal number of interfaces component/part and increased both part size and integration level
- New cabin and cargo systems with regard to power architecture and communication (optical and wireless communications, eco-efficient power and supply systems, etc.)
- New cabin and cargo architectures and operational procedures (platform and flexibility concepts, crew workload, passenger flight experience, baggage handling, etc.)
- Environmentally friendly cabin materials and fire protection.
- Culture specific cabin architectures

**Calculation methods and design principles for integrated structural, system, and cabin elements:**

- Technology validation at virtual and physical full scale
- Predictive numerical methods for complex and highly integrated structures
- Accurate understanding of structural behaviour of highly integrated single and double curvature fuselage sections operating in close-to-real conditions
- Accurate understanding of structural behaviour of highly integrated lower fuselage elements
- Numerical simulation methods and tools to predict, respectively calculate full 3 dimensional loads and stress cases for the next generation fuselage including a complex mixture of materials, parts and subassemblies and including features and parameters of manufacturing
- Numerical simulation methods and tools to accurately predict the next generation fuselage structural behaviour in cases of limit loads and ultimate loadings and cases of impacts and crash cases relevant for certification

**Manufacturing technologies for integrated structural, system, and cabin elements:**

- Advanced manufacturing means and methods able to achieve high production rates with reduced recurring costs
- Integration within a “future factory” vision, enabling among others: intelligent automation, ergonomic work environment, optimum human-machine interface, zero defects and flexible manufacturing lines
- Low cost manufacturing of complex parts
- Automated composite material production processes enabling high volume manufacturing rates
- Application of new metallic alloys and composite material developments at a lower cost
- Application of composite materials with shorter curing cycles
- Automated fibre optics structure integration process

**Testing technologies for integrated functional and mechanical demonstrators:**

- Multi-purpose testing and certification procedures
- Validation of breakthrough technologies by simulation and physical test beds
- Validation of disruptive structural concepts and architectures
- Validation of manufacturing and assembly technologies
- Understanding of certification implications of multifunctional and highly integrated concepts
- Correlation and validation of new numerical capabilities
IV. High-level WBS and work-sharing

In terms of technical work organization, activities in Platform 2 will be set up according to four high-level work packages: Platform Management Office, Integrated Product Architecture, Non-Specific Design Technologies and Technology Validation.

WP0 - Platform Management Office

WP0 “Platform Management Office” is a combination of support functions relatively small in terms of size, but very important in order to guarantee a successful execution of all the integration work planned in Platform 2. In view of the large size and complexity of Platform activities, which are distributed across a consortium of numerous partners from all around Europe, a strict project management control and transparent decision-making processes need to be implemented. The common Grant Agreement already provides the basic principles for the project management and states the role and obligations of all contractors. In addition, a Consortium Agreement is to be implemented, which handles legally binding commitments, terms and conditions in the IADP partnership, including the management of intellectual property rights.

The management will comprise all proven management procedures and principles that are well-known and proven from other large projects. Lessons learned from Clean Sky 1 will consequently be considered to implement best practices for Clean Sky 2. This applies to all kind of management activities, from day-to-day business over consequent technical progress monitoring, close financial controlling, strict risk management, lean reporting and decision making, while building-up and maintaining an efficient team spirit among all parties.

Regular reviews will be executed to assess the project progress with regard to deliverable availability and quality, adherence to the master time schedule and cost expense plan. If necessary corrective actions will be proposed and an action plan will be validated, as well as the refinement of the work plan for the next project period. At particular decision gates, major external stakeholder will be invited to interact with the project: at project start to contribute to the initial operational scenario assessment, at mid-term stages to receive periodic reviews on the approach taken and the achievements made, and at the final stage to comment on the best way towards marketable products and systems.

Besides the classical project management and controlling activities, this work package will ensure the right level of alignment and synchronisation within IADP-Platform 2 and between this platform and LPA Platform 1, ITD Airframe and ITD Systems. Interfaces with eventual confluent programmes outside Clean Sky 2 (which could be executed within other major funding programmes like the German LuFo, the French PIA2, the British ATI, etc.) will be controlled and monitored from here.
WP2.0.1: Project Management Office

- **Scope and Deliverables:**
  - Scope consolidation and adaptation
  - Monitor and control scope
  - Monitor and control deliverables

- **Time:**
  - Overall planning consolidation
  - Plan schedule management
  - Monitor and control schedule deviators

- **Cost:**
  - Plan cost management
  - Manage cost targets
  - Monitor and control costs

- **Risk & Opportunity:**
  - Identify risks and opportunities
  - Manage mitigation actions
  - Monitor and control risks

WP2.0.2: Platform 2 Partner Coordination

- Coordinate partner activities
- Organise and follow up platform 2 reviews
- Organise reviews with funding authorities
WP2.0.3: ITD Interface Management

- Coordinate the interface to the ITD Airframe and ITD Systems
- Coordinate the interface to further funding projects (EC and national)

WP2.0.4:

- Dissemination of the project results:
  - Posters
  - Events
  - Web-presence
  - Movies
- Dissimilation of documents and papers

WP2.1 - Integrated Product Architecture

The next work package, “Integrated Product Architecture”, will be firstly dealing with the compilation of requirements and functions that the integrated concept is expected to fulfil, and defining a lean process for cascading them down to sub-components, modules or elementary parts. High level architectures, like the ones for electrical systems will be defined and assessed within this work package. The largest amount of effort will be devoted to assessing innovative integration approaches in order to understand their benefits and impacts. The result from this exhaustive work will be the configuration of the best overall integrated concept. Arbitration between different approaches will be performed through trade-offs (e.g. benefits/penalties of reduced/increased flexibility, load carrying or multifunctional elements, passenger comfort, etc.) and a final value assessment of best candidates will be provided.

WP2.2 - Non-Specific Design Technologies

The third high level work package “Non-Specific Design Technologies” will be hosting innovation activities that need to be matured in order to be incorporated into the demonstration phase and whose main axis of research are more disciplinary-oriented than integration-oriented. Some of these necessary technologies and activities are: the preparation of numerical methods for predictive virtual testing, maturation of technologies for elementary parts and sub-components, assessment of disruptive build-up concepts, development of tools for systems enhanced installation, technologies for cabin operation, enablers for passenger comfort and services, etc.

WP2.3 - Technology Validation

Finally, the fourth major work package will be conducting the necessary demonstration work so as to bring the innovative concepts and matured technologies up to a TRL 6. Activities in this work package will start in a very early project phase in parallel to the other research, because new multipurpose testing procedures will need to be developed in order to validate multifunctional products and increase effectiveness at the same time. Besides this, most of the activities will be focused on the design, development and testing of the required full scale demonstrators.
The main demonstrator to be built is the one dedicated to the multipurpose validation of the best fuselage, cabin and systems integrated concept. However, the need to test some specific components will lead to the development of two focused demonstrators: next generation cabin and cargo functional demonstrator and next generation aircraft lower centre fuselage structural demonstrator. The reason for an aligned, but with respect to the demonstration separation of the two routes is that the demonstration of a number of structural features do critically include the application of specific loads profiles for typically long duration, including overloading and damaging loads levels at the end of the tests, while the integrated testing of cabin, cargo and other aircraft systems into the fuselage require a demonstrator in reasonable shape, without the constraints of equipment attached to apply and measure severe loads.

Research in a manufacturing environment receives special focus with a dedicated sub-work package called Pre-production lines. Main targeted benefit of this sub-work package is the definition, testing and validation of the key steps of a next generation integrated fuselage manufacturing and assembly, including the associated major cabin and system components. The definition of the assembly concept will also target further simplification of the integrated design, which could lead to the identification of additional weight savings.


Going beyond the state of the art in terms of unconventional integration of functions requires a complete new mind set on how to fulfil requirements and how to evaluate potential solutions. In fact, the classical mono-disciplinary optimisation approach cannot fulfil the expectations in terms of performance and effectiveness and here is where a new approach is required. Activities in this work package will seek firstly to understand what are the top level requirements and functionalities that need to be fulfilled. This exercise will also enable a larger understanding of the effects at overall aircraft level of limiting or extending certain functionalities. A lean process for cascading requirements down to sub-components, modules or elementary parts will be defined. Innovative global architectures will be developed, analysed and proposed at this stage in order to ensure a real multi-domain concurrent innovation process. Certain local solutions (e.g. structure stabilization by means of cabin monuments and, electrical or mechanical systems with structural functionality, integrated cabin/structure interfaces, etc.) will be also assessed through trade-off studies, in order to include the most beneficial ones in the final configuration.

This work package enables a close cooperation between all involved disciplines. From the combination of cabin and cargo, structure and system experts, new integrated solutions will be defined which potentially might imply significant changes in the development and manufacturing processes of airframe’s structures and cabin. The today’s way of working in separated domains will move to an integrative way of conducting design, development and manufacturing in the future.

This work package will rely on technologies coming from contributing programmes and on the ones being matured in WP2.2 “Non-Specific Design Technologies”. Then it will decide according to what has being described before how and up to what extend those technologies will be incorporated into the final solution.

The results from Value Assessment are one of the major outcomes not just from this work package but from the whole Platform 2. Besides them, this WP2.1 will provide an essential input to WP2.3 where the best solution will be materialised in a full scale demonstrator. By means of all the activities and studies undertaken here, this work
package will be responsible for conducting and delivering all consolidated value assessments needed in this platform.

![Platform 2 - WP0](image)

**Platform 2 - WP0**
Innovative Physical Integration Cabin-System-Structure

**WP 2.1**
Integrated product architecture

**WP 2.1.1**
Requirements and functions

**WP 2.1.2**
Integrated product definition

**WP 2.1.3**
Value assessment

Figure 6.16 – WP2.1 Principle Work Breakdown Structure (WBS)

**WP2.1.1 - Requirements and Functions**

The purpose of WP2.1.1 is to define, analyse and prioritize all relevant requirements and functionalities. Methodologies for lean down-cascade of requirements will be defined, assessed and implemented here.

Nowadays, the specification and development of new aircraft presents a clear distinction between the different ATA chapters and functions. Even in the domain of structures there exists a strong separation between primary and secondary structure. This approach has brought several benefits in the past like the accelerated development of specific skills such as stress, design or manufacturing. It has also advantages in terms of airworthiness, since it simplifies the certification in front of the authorities. However, the current level of integration presents inefficiencies that the state of the art of the technology cannot overcome.

Keeping in mind the objectives of the platform, the effect of requirements on key parameters will be analysed and in some cases challenged in order to move towards an innovative overall optimisation. For example, highly integrative approaches can lead to changes with respect to customization compared to the state of the art solution. It could affect the visible cabin area as well as the installations covered behind linings and their way defining functionality, e.g. electrical network architecture, routing and manufacturing.

Another important field of activity within this work package will be the alleviation of certification constraints and challenge of design rules and requirements. Keeping in mind that safety requirements are not negotiable, there is still room for improving over-penalising rules. The work will be conducted in collaboration with partners and certification authorities and is aimed at tackling a wide scope of domains in order to identify arbitrary rules:

- Directives on structure and system failure
- Structure design and construction
- Cabin and Cargo
- Maintenance and maintainability
- Flight loads
- Associated safety factors

The work on certification rules will not be limited to eventual challenges of the content. Since disruptive solutions are expected out of this project, a way to certify unconventional structures and systems architectures needs also to be proposed in cooperation with airworthiness organisations. Questions like “how to certify cabin monuments or systems that carry structural loads?” will have to be answered.

In terms of cabin operation, the demographic development and the cultural divergence of the world’s population could lead to diverging requirements. This can result in an area of conflict between simplified customization and to serve all requirements. A worldwide passenger survey will validate the different requirements.

After all requirements and functionalities have been collected and analysed, an assessment process will rank them in order to ensure fulfilment of top level objectives applicable to the “Innovative Physical Integration Cabin – Systems – Fuselage”.
WP2.1.2 - Integrated Product Definition

Higher integration levels and the merge of cabin and systems within primary aircraft structure are key concepts to reach new targets in terms of weight reduction, enhanced space utilization for passengers and cargo, as well as reduced manufacturing cost. Effectively, an integrated structure-cabin-systems solution can provide several improvements in function and properties as:

- Reduction in total weight
- Reduced part-count
- Simplified system routing and their attachments
- Increase of additional space
- Better understanding of size and shapes drivers

Starting from the requirements defined in WP2.1.1, the aim of the activities conducted in this work package is to study different concepts and architectures for an integrated next generation fuselage architecture, which combines all key technologies for the use of the most advanced materials and manufacturing methods for a high ramp up, high production rate fuselage structure, integrates a next generation cabin and cargo setup, takes all relevant requirements and specifications of the related integration of physical modules, parts and monuments, and integrates all relevant systems for principle operation of the aircraft and cabin and cargo. System installation shall encompass a wide scope beyond electrical and hydraulic components installation, but also air ducts, venting systems, water infrastructure and oxygen.

On one hand, overall architectures will be developed and analysed as a top-down input for the final solution. On the other hand, specific local solutions will be evaluated and eventually proposed to be incorporated into the final configuration. All these different approaches are targeted at materializing synergies with CFRP/metal fuselage properties and a cabin introducing additional load paths through its elements and simplifying the structural integration.

After having improved the performance, the integrated concepts and ideas shall also be able to meet cabin specific requirements: customization to passenger/airline needs. Those might differ significantly due to different business models, but at the same time shall not penalize the basic aircraft. So standardization as means of choice is also to be considered. Today different customer options for cargo features impact several ATA chapters for available solutions. However, this leads to the necessity to select options at a very early stage and thus reduces the flexibility of manufacturing. In order to allow for a standard aircraft that is flexible for all possible customer options, the simplest way is to equip the major modules with all their possible optional parts. This solution orientates at the most complex option the aircraft manufacturer offers to the customer, but - on the other hand -
comprises obsolete features from complex variants and thus leads to unacceptable weight impacts. In order to overcome this problem, the research will focus on merging functions of different parts & ATA chapters. This concept provides a promising concept for enabling a standard aircraft without penalising either the performance or the options for the customer.

Despite all the benefits that high integration can offer, there are still some risks associated to this disruptive focus. The major risks linked to a high level of integration are:

- Difficulty to identify the optimum solution (Recurring Costs, Non-Recurring Costs, lead time, weight)
- Synchronisation of technologies
- Lack of understanding of failure modes (system, structures)
- Customisation complexity
- Means of compliance
- Identification of clear requirements

This platform is well suited with enough mechanisms so as to mitigate these risks, like clear requirements definition (WP2.1.1), conduction of concept trades (WP2.1.2), accurate programme and interface management (WP2.0), development of certification rules (WP2.1.1), validation of predictive virtual testing (WP2.2) and development of test means (WP2.3).

**Work content and methodology**

From a methodology point of view, a stepwise approach will be followed to ensure that the whole spectrum of integral solutions is screened. Starting from a high level functional requirement, for example structural efficiency, the work to identify potential solutions will be organised as follows:

- **Flexibility of interfaces**
  This stream will analyse the benefits in the fulfilment of the primary functional requirement when the flexibility in the interfaces with surrounding domains (or ATA chapters) is reduced. Following with the example of structural efficiency, analysis on the impact of cabin & cargo, electrical systems and mechanical systems flexibility can lead to new solutions like new attachments or new monuments. This analysis can lead also to innovative ways to maximise standardisation and to minimise customisation.

- **Load carrying elements**
  Research in load carrying elements will look to specific modules suitable to undertake structural responsibility. Some of these elements could be cabin and cargo lining, monuments, hatracks, cockpit wall, module integrated with pressure bulkhead, harnesses contributing to static and crash cases, etc. Benefits of these local improvements will be assessed through trades in order to quantify the effects. Best candidates will be part of the final configuration.

- **Multifunctional solutions**
  The new way forward is the integration of parts from different ATA-chapters, which are currently designed separately and integrated afterwards. So there will be a merger of functions from structure, cabin and systems related parts. This integrative approach is leading to fewer but also more complex parts with multiple functions, requiring a more sophisticated design and an enhanced validation process that will be tackled in WP2.3.
Cases like the structural door and window cut-outs are, from a structural viewpoint areas were the optimal load path is disturbed leading to solutions of complex design and costly materials. At the same time, the cylindrical area of the fuselage & cabin is characterized by numerous repeating parts which have to be installed in consecutive sequence. The shifting of interfaces and a decoupled assembly are underlying ideas that could generate new concepts like a highly integrated aircraft side element from door to door, consisting of windows, primary structure, insulation, cabin lining and systems in one part (window belt) and including as few interfaces as possible. Such element could be manufactured as a module independent from the aircraft serial production, enabling automation while avoiding tolerance issues between cabin, windows and structure (see figure 6.13).

![Figure 6.18 - Window Belt](image)

One enabler for multifunctionality comes from the application of nanotechnology, in particular nanomaterials. Even though the development of new materials is not part of the work planned in this platform, the enhancement of structures and components through the use of nanoadditives will be studied. In this sense, certain properties for the structural components could be altered in order to improve certain characteristic and behaviours like for example: electrical and thermal conductivity, toughness/Damage Tolerance improvement, surface functionalization, Vapour/liquid barrier, etc. The inputs needed for these studies will come from projects and initiatives like for example the Graphene flagship, which aims at identifying/developing industrial applications for this nanomaterial (flexible/transparent displays, embedded sensors, etc.).

- **Disruptive architectures**
  Some of the concepts that will be analysed in this work package represent real breakthroughs in aircraft conception and therefore cannot be considered as local improvements. Ideas like “minimised number of cut-outs” require also an architecture level perspective in order to be developed and analysed. Some other conceptual streams at architecture level could be considered here as drivers for the final solutions like the waterless operation or the environmentally friendly and recyclable aircraft.

Relatively small in size, but of very high relevance for a next generation fuselage-cabin-cargo integrated concepts is a complete review and re-thinking of the system installation. The scope of activities shall encompass the full range of systems to be installed, in particular electrical and hydraulic installation with active and passive components, wiring, harnesses tubes and vent lines. Develop and mature innovative solutions in systems installation is a key enabler for a multidisciplinary layout of the large demonstrators in
WP2.3.1. Part of the requirements for the technology definition and development in WP2.3.1 will be provided through output of WP2.1

Since the system architecture is the starting point of an integrated physical integration, it is mandatory to consider it as a major lever to simplify and enable an integrated solution. All physical characteristics will be challenged in order to fit in a highly integrated and optimized aircraft. The minimum footprint could be achieved by considering the following system architecture:

- Distributed architectures: instead of having large avionic equipment located in few areas in the aircraft, some trends propose to have more equipment but sharing more function. This approach limits the number of long harnesses all along the airframe, constituting a wired or wireless “network”
- Electro-Magnetic emissions and short circuit events are leading to segregate electrical routes. This segregation could be avoided by advanced protection in Equipment or in harnesses that would allow to regroup routes
- Some pipes have particular heating functions, involving several additional parts (sensors, heaters, bounding point) and could be avoided if pipes integrated those functions by design on the connection.

**WP2.1.3 - Value Assessment**

The objective of WP2.1.3 is to conduct and deliver consolidated assessments of the benefits enabled by the different integrated solutions. These activities will be closely linked to the demonstration and testing phases conducted in WP2.3 in order to complete the verification and validation loop.

Revolutionary and disruptive concepts like the ones developed in Platform 2 are expected to bring enormous benefits, but these concepts are also associated with uncertainties regarding feasibility, savings in terms of weight and cost reduction, suitability for industrialization and customer acceptance. Thus, the strict value assessment conducted in this work package is a crucial input in order to de-risk the development of breakthrough technologies and to concentrate the work on the ones that deliver the highest benefit and at the same time are feasible. Key for this risk management is the close collaboration between all involved disciplines, in particular in close alignment with the progress in the associated structure research.

For ensuring costumer acceptance, it is foreseen to periodically invite potential costumers and other major transport stakeholders to interact with the project and to feed-in their operational perspective to the envisaged new concepts. In particular for radical new approaches, the stakeholders’ contributions to initial operational scenarios and concepts assessment are key to substantially de-risk the research towards a mature and marketable product. To ensure that aspects of certification of the proposed and developed new concept are appropriately addressed in this work package a first close cooperation with releant authorities shall be established via existing links (Airbus Design organization approval) e.g. example between Airbus and EASA).

**I. Planning roadmap, targeted technology readiness levels**

Due to the nature of WP2.1, ultimately to define the configuration of the large Platform 2 integrated demonstrator, the schedule is tightly aligned to the roadmap of WP2.3 with indicative closure of activities between 2020 and 2023, depending on the disruptiveness of the final configuration and the involved technologies. There is no explicit contribution to reaching specific TRLs of the technologies tackled in Platform 2.
II. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

Interactions with the Airframe ITD and Systems ITD will be established and managed through WP2.0 “Platform Management Office”.

The development of a next generation fuselage including an innovative cabin and cargo concept is including all related systems which are part of this new cabin and cargo concept, but also all other auxiliary and main aircraft systems that will be included in the fuselage area. In this course, WP2.1 will have an interface with the Systems ITD, in particular to the technology work packages relevant for the integration of systems to the fuselage (electrical power systems, systems related to thermal management, etc). It is planned that selected actors from the Systems ITD but also additional partners in the systems sector will contribute.

Experiences and results from large demonstrator programs like the European Commission funded level 2 projects MAAXIMUS or ASHLEY will be taken to feed their deliverables into Platform 2, in order to mature and integrate the various key technologies into a coherent, synergetic demonstrator.

As for all other demonstrators, there is a mainline exchange planned with the TE and Clean Sky 2 Eco-Design work packages to provide relevant results of the integrated flight tests as described in the related chapter.
6.6.2 “Non-Specific Design Technologies” – WP2.2

a) Work Breakdown Structure (WBS)

The individual technology development for “Innovate Physical Integration Cabin – System – Structure” will be conducted within six major streams and several specific roadmaps that will be developed in synergy with ITD Airframe, ITD Systems and the other platforms in Large Passenger Aircraft IADP. The WBS for non-specific design technologies is as follows:

![Platform 2 - WP0
Innovative Physical Integration Cabin-System-Structure](image)

**WP 2.2**
Non-specific design technologies

- **WP 2.2.1** Predictive virtual testing
- **WP 2.2.2** Technologies for elementary parts, subcomponents and modules
- **WP 2.2.3** Technologies for future aircraft factory
- **WP 2.2.4** Interface technologies
- **WP 2.2.5** Customization technologies
- **WP 2.2.6** Airframe and Cabin & Cargo operation

**Figure 6.19 – WP2.2 principle Work Breakdown Structure (WBS)**

**WP2.2.1 – Predictive Virtual Testing**

The use of advanced numerical techniques for the simulation and prediction of structural behaviour plays a continuously increasing role in the development of new aircraft. Techniques such as the finite-element method are used extensively, from the prediction of material coupon behaviour up to detailed models of entire aircraft/aircraft components. Today, in the case of the A350, a Virtual Full-Scale Test (known as ViFST) model has been developed to support the program and de-risk the major static tests, which pushes the boundaries of model size and complexity. This serves to underline the importance of this technology for the future. This novel integration of simulations and physical tests will better optimise and reduce the extent and cost of the test pyramid but will
require approval by certification authorities via the support from the relevant Designated Certification Specialists solicited at key points during this WP.

Underpinning and essential to the success of this work is the ability to isolate detailed areas of potential failure initiation and to accurately capture and simulate the failure progression process. Reliable, physically based methods with meaningful and measureable input parameters are therefore necessary. The aim of the work will be to reach TRL 6 maturity level in a number of new numerical simulation methods for both composites and metallic components and features. At TRL 6, the method under development will need to have a proven predictive capability and well understood perimeter of applicability in terms of loading types, geometry, materials, etc. This will then be demonstrated with the use of a blind test simulation validation approach. A validated method will need to have a sufficient level of proven maturity for it to confidently be used to reduce test program costs, risks and cycle time. By the implementation of true extrapolation capabilities, these new methods will then become an essential tool for the development of disruptive and innovative concepts.

Some of the specific key areas where it is planned to significantly develop Predictive Virtual Testing (PVT) methods further are:

- PVT of Integral Joints (e.g. Skin / Stringer debonding simulation and prediction)
- PVT of Fastened Joints (e.g. bolts, rivets)
- PVT of Laminated Composite Coupons
- PVT of Metallic Coupons
- PVT of 2nd Generation Composites (e.g stitched, woven, thin plies, etc).

In order to achieve robust validation of new predictive virtual testing methodologies, several strategic test enablers will be developed such like:

![Figure 6.20 – Process for Maturing New Numerical Methods](image)
Automated data correlation

The purpose of this package will be to develop objective standard processes for efficient data comparison of models to allow automation and greater efficiency. Integrating simulation with measurement systems output would allow “total comparison”, therefore achieving robustness of the virtual test philosophy. Integration of these capabilities on large scale models (demonstrators) would be pursued in WP2.3.2 “Testing”.

Full field strain measurements (Thermoelastic Stress Analysis -TSA-, fibres, S/G alternatives)

Current state of the art for strain measurements typically employs strain gauges, providing single point data. Advancement in optical methods, among others, could enable non-contact full-field strain and deformation measurements, acquiring multiple data points ($10^4$-$10^5$) at lower cost and lead time. Technologies for all types of tests (fatigue, static) would be developed, and would provide invaluable data for robust and accurate simulation model validation. Certain technologies, such as thermal methods or optical fibre, would also be enablers for other key areas, such as testing of cabin and system, SHM, in service inspection, etc. These developed enablers would then be applied and validated on a large scale in WP2.3.2 “Testing”, delivering benefits such as reduced test lead time and risks.

Generic technologies (enablers) to ensure flexibility and applicability

Other generic technologies, such as acoustic methods, should be developed to further enrich current testing capabilities. With the proposed advancements in simulation, enablers allowing for a better understanding of structures and materials (notably composite technology) are required. Acoustic methods would allow for live damage tracking, anticipation of failure, and characterization of failure modes, which aligns with the predictive virtual testing philosophy (re-enforcing and validating that technology). Such capabilities are to be used in other areas, such as cabin and system testing (acoustic methods already being utilised for noise detection, comfort, etc.), in-service inspection (live NDT) and maintenance. These “Multi-Purpose Testing” technologies should reduce lead time during the testing of demonstrators, by requiring simpler generic test setup-up that suits structures, system, cabin test and validation of numerical predictions, saving cost and improving robustness, while providing a step-change in structural optimisation, reducing airframe weight.

This work package is planned to be fed by important research projects that are already running, like the EU FP7 MAAXIMUS, which aims at achieving the fast development and right-first-time validation of a highly-optimized composite fuselage as a result of a coordinated effort between virtual structure development and composite technology.

WP2.2.2 – Technologies for elementary parts, sub-components and modules

Prior to the design, manufacture, assembly and test of the final full scale platform some initial evaluations will be performed at an element level, sub-components and modules. The results will be used in the down-selection for application to the demonstrator developed in WP2.3.1. Manufacturing cost and weight analysis will be performed in conjunction with WP 2.1.3 to assess the value of technologies and design. The activities in this work package will be organised around two major streams: Validation of structural integration concepts and Innovative manufacturing processes.

Validation of structural integration concepts
Representative details of different structural solutions will be developed and tested, in order to support the final integrated product configuration as well as the final material selection for the demonstrator. The need to perform developments for specific details is driven by the complexity and high level of integration required in this platform. On one hand, solutions for higher integration need to be down-selected, and for this reason it is required a detailed assessment study of the viability, benefits and implications of each alternative. On the other hand, attempting to integrate these disruptive solutions directly in the final demonstrator without any intermediate step would simply add too much risk on the execution of the project.

Concepts assessed in this work package will cover details like innovative welded joints (e.g. composite welding, friction steer welding, etc.), 3D integrated structural reinforcements, or multifunctional local solutions (e.g. Multi Integrated Window Belt, Integrated Doorframe and Cabin Parts, etc.)

- **Innovative manufacturing processes**

New manufacturing processes for both composite and metal structural parts are an essential enabler for the final solution. The performance of these manufacturing processes will support the decision on the material finally selected for the demonstrator. Besides this, all technology developments will point in the direction of having new manufacturing processes that on one side enable the production of highly integrated parts and at the same time are more efficient, robust and able to fulfil high rates of production.

Technologies enabling rivet-less assembly will be considered here due to their relevance in enabling dustless and automated assemblies.

Manufacturing technologies addressing net-shape production is another important building block, able to significantly bring down recurring costs and costs of non-quality. Within the area of net-shape manufacturing, the Additive Layer Manufacturing (ALM) is a key technology enabling the integration of new design principles into components, modules or structure and to improve the environmental performance of products compared to state-of-the-art manufacturing methods. In fact, ALM together with investigations on “bionic design principles” by using Multi-Objective Optimization (MOO) and Multi-Material Optimization (MMO) could push the paradigm change in product design forward.

**WP2.2.3 – Technologies for Future Aircraft Factory**
The research on an “Innovative Physical Integration Cabin – System – Structure” would be incomplete if the enablers for the Future Aircraft Factory were not considered. In order to reach a true TRL 6 maturity level in disruptive concept architecture like the one developed here, manufacturability needs to be regarded as important criteria in the validation process. Although the integrated pre-production tests will be conducted in WP2.3.3, the first step will be to develop specific technology bricks, and this is precisely the objective of this work package.

In the vision pursued in this project, the “Aircraft Factory of the Future” will be affected by increased automation and high flexibility coupled under the pressure of continuous improvements. New manufacturing technologies and functional integrated design have the opportunity to meet these challenges. The pre-production lines planned in WP2.3.3 will bring the adequate environment to validate a true TRL 6 maturity level of the demonstrators. However, there are several technology bricks that support the Future of Aircraft Factory vision, whose development do not need to be synchronised with the specific design activities of the demonstrator. Therefore, the aim of this work package is to give reality to the transformation of our production shops using various advanced methods and technology bricks families such as:

- Automation
- Smart production
- Virtual Manufacturing System
- High precision handling and logistic
- Structure mounted system
- Operator booster, Generic and universal robotic worker
- Standard robot and Collaborative robots (Cobot)
- Agile Speed shop
- Intelligent production

All the relevant advanced methods and technology bricks will be applied in the product architecture configuration phase (WP2.1.2), in the design and execution and the demonstrator (WP2.3.1) or in the set up and testing of the pre-production lines (WP2.3.3).
The installation of cabin and systems in the fuselage is nowadays a large contributor to the lead time and cost structure of any commercial aircraft. At the same time, the systems architecture in commercial aircraft is subject to clear challenging trends like the introduction of a “more” or even “all electric” aircraft, the need for more decentralised energy distribution. Data rate requirements represent an additional challenge, since they experience an ever-increasing demand that can only be satisfied with a new generation of high performance on-board communication systems.

This work package will undertake the development of certain technologies, multifunctional concepts and advanced methods aimed at simplifying the integration of systems either by reducing part counts, reducing labour time or improving systems’ specific efficiency.

The activity will be organised in two major streams: Advanced data and power distribution and Innovations in Systems integration. At the same time, the programme interface management with ITD Systems will allow the integration of technologies developed on that platform.

- **Advanced Data and Power Distribution**
The development of the connected aircraft requires the management of data security issues between non-safety and safety relevant communication domains. Non-harmonized aircraft, airline and airport communication infrastructure and communication interfaces have to be handled.

The connected aircraft proposal shall allow a seamless integration of the aircraft and its cabin & cargo communication system into the airline operational network based on an intelligent and secure communication management between all communication domains.

Besides this, automatic configuration of connected wireless /wired clients and wireless automation of airline operational tasks will be developed. Fundamental solutions for certification issues of a fully connected aircraft shall be defined.

Solutions that will be studied and developed include:
- Wireless connectivity
- Contact less connectivity
- Easy electrical bounding connections
- Local power generation & supply
- Maintenance free energy sources
- Smart grid power distribution

### Innovations in Systems Integration

The integration of cabin and systems in the structure can be drastically improved by means of new tools and multifunctional concepts. All of them will be preliminarily developed in this work package and then released for its consideration in the Product Architecture Definition (WP2.1.2) and ultimately in the final full scale integrated or cabin functional demonstrator. Some examples of advanced solutions for improved cabin and systems installation are: embedment of fibre optics and wires in structures or cabin monuments, tool-less connectors, flexible connectors, multi-functional foam ducts, etc.

The embedment of fibre optics is prerequisite for realizing an Optical Structural Network (OSN), i.e. a structure integrated, ubiquitous, fibre optic-based resource for the distribution of information (digital data, sensor signals, RF, low power...) throughout the airframe. The OSN concept saves “harnessing” weight, reduces required installation volume as well as eliminating many of the installation process steps associated with classical harnessing means. The OSN is not limited to primary structure; it could cover all additional potential structure integration possibilities, e.g. cabin lining, hat-racks, raceways and ducting, whether used for direct monitoring of such parts (SHM) or simply as a mechanical host/ carrier for the fibre. Robust, affordable OSN connection technology must be developed to enable the access and egress of light from the OSN to end system users. The industrialisation and effects of the integration of the OSN in the structure during the whole lifecycle of the aircraft will also be studied.

**WP2.2.5 – Customization Technologies**

The need to address fast changing customer wishes and passengers expectations resulting from rapid developments in terrestrial technology is one major driver for future aircraft. Especially, the aircraft cabin environment has a major impact on the passengers’ flying experience, since the cabin and cargo functions have a direct effect on the fulfilment of the flying travellers’ needs and expectations. Consequently, it is subject to high
levels of customization and undergoes far shorter life cycles than the airframe itself, i.e. the encircling fuselage and the basic aircraft systems that the cabin is interfacing with.

Additionally, disruptive aircraft concepts with new deck configurations for high payload, fast ramp up and reduced manufacturing costs require appropriate cabin & cargo architectures. The platform concept ensures increased revenue by limiting non-recurring and recurring costs whilst ensuring ramp-up and a reduction of development risks for a similar customization level. An additional source of customer revenue is expected as a direct consequence of the platform approach as this raises residual aircraft value, thereby reducing direct operating costs for the airlines.

Today’s development and customization of cabin and cargo are carried out somewhat independently from other aircraft disciplines, which sets narrow confines to the optimization of the cabin in terms of weight, revenue space, manufacturing cost, etc. Key to achieving a step-change improvement in future aircraft design is to cross the functional boundaries between aircraft classical design disciplines, in order to minimise the impact that customisation has on structures and systems.

The main objective of this work package is therefore the development of a novel cabin and system architecture serving future airline and passenger’s needs, whilst enabling the aircraft manufacturer to benefit from reduced customization efforts.

An aircraft platform, which is able to accommodate these modifications without the efforts needed today should be developed allowing also in-service modifications without adapting the basic aircraft. The development of such a platform allowing high customization flexibility is one of the main research objectives of this work package. The platform "flex concept" shall ensure increased revenue by limiting non-recurring costs while ensuring production ramp-up and a reduction of development risks at similar customization level. Customer revenue is expected as the platform raises second life value reducing direct operation cost.

**WP2.2.6 – Airframe and Cabin & Cargo Operation**

The operation of an airframe with highly integrated structures, systems and cabin represents a great challenge that needs to be addressed in order to deliver a viable product. Maintenance is certainly a main procedure for aircraft operators. Airframe operating conditions will be studied in close link with WP2.1.1 and new maintenance solutions will be developed considering technologies like SHM in order to ensure operability in the context of the
scenarios developed in WP3.6 Maintenance. Furthermore it shall be investigated how a highly integrated C&C network supports future prognostic and diagnostic means. The customizing of Cabin and Cargo in the lifecycle drives those networks as well as the need for simplified architectures and the integration into aircraft systems needs. It has also to be investigated how testing needs can be reduced in order to satisfy FAL needs beside operability needs in aircraft life.

At the same time, demographic developments (increased obesity, aging of passengers) and the cultural divergence of the global population further impact the airlines needs to generate ancillary revenue with additional services through novel cabin designs and operational processes. The resulting amount of options and hence possible cabin configurations require an aircraft platform, which is able to accept these modifications without the considerable customisation effort and cost experienced today. Also in-service modifications should be possible without adapting the basic aircraft.

![Airbus vision for a “disruptive” human-centred use of space of the aircraft fuselage](image)

- **Culture specific cabin architecture**

  Passenger surveys, trend analysis and psychological investigations will gain knowledge about future passenger expectations and cultural divergence. These results will be the baseline for the development of the new cabin components, architectures and operational processes for passenger guidance and baggage handling.

- **Virtual passenger guidance and outside view**

  Novel cabin and system architectures for disruptive aircraft may require virtual outside views of the aircraft environment, in order to ensure the passenger’s acceptance. Especially in areas without windows, virtual outside views for orientation will deliver a completely new flight experience. Smart solutions by means of visualisation technologies have to be developed. Basic technologies for holographic projection or display are not yet available for 3D objects.

  Depending on the best matching technology, new service opportunities will be developed for increased operator revenues and customer comfort. These services shall target passengers as well as cabin crew and ground personnel. In a first step, current technologies for augmented and virtual reality will be integrated into the aircraft environment and combined with existing cabin crew functions, in order to enable efficiency comparisons. In a second phase, new features will be implemented, in order to show the potential of the chosen technical solution and provide an outlook for business opportunities and potential integration of other technologies.
Seamless guidance especially for physically challenged passengers is currently not available. The research work will include the identification of customer acceptance criteria and the design of the interaction process between crew and passenger in the virtual environment for visual guidance. Visual support shall also ease and accelerate today’s cabin boarding by helping the passengers to reach their seats more quickly and thus shortening the aircraft turn-around time. In addition, a fast de-planning scenario or an evacuation could also be supported by enhanced visual passenger guidance.

- **Crew workload**

The impacts of these developments for the cabin crew working environment have to be investigated. The overall workload of the cabin crew during flight operation shall be minimized by the introduction of supporting technologies and novel operational processes. The related work package shall address the interfaces and required interconnections with the aircraft infrastructure as well as mandatory passenger oriented cabin operation procedures and scenarios.

- **Innovative baggage handling**

In order to increase the efficiency of airport operations and enable reduced turn-around times, new concepts for the handling of checked-in baggage as well as carry-on items are required. Since the operational models of airlines may differ considerably, the concepts will provide a modular approach, in order to achieve better market acceptance and reduce the impact on airport infrastructure. These modules shall address e.g. automated processes, tracking solutions, architectural adaptations for altered ratios of check-in and carry-on luggage volumes or dedicated baggage space. Some of the concepts may also be an influencing factor for innovative aircraft designs.

- **Environmentally friendly fire suppression**

Environmental challenges are being addressed with the development of a new cargo hold fire suppression system. Alternative agents to the currently used Halon have an impact on the overall system architecture. The fire suppression performance of each of the candidates must be thoroughly evaluated with extensive testing, also taking into account environmental and toxicological parameters. To achieve compliance with airworthiness authorities, regulatory bodies like EASA and ICAO will be involved from the beginning.

- **Independent Cabin Supply Systems**

Simplification of cabin customization can be achieved by introducing decentralized energy sources located in or near the cabin. Especially supplying the galleys, which are the major cabin consumers of electrical energy, with decentralized power sources enables multiple new configurations that were previously not supported by the electrical network. Later cabin reconfiguration will also be significantly easier in case of moveable power sources. Eco-efficient power sources like fuel cells being applied to non-essential applications in the cabin (like galleys) are seen as a stepping stone towards further implementation in other areas of the aircraft. The trend towards a more electric aircraft forces industry to rethink electrical power architectures. Furthermore, the use of e.g. fuel cell by-products heat, water and oxygen-depleted air will further boost the efficiency in electrical power generation.

b) **Planning roadmap, targeted technology readiness levels**
This work package will develop mature technologies in accordance with the functional requirements cascaded from WP2.1.1. Details will be provided to WP2.1.2 in order to assess the convenience of integrating these technologies into the final demonstrator. In specific cases like testing technologies or technologies for future of aircraft factory will be delivered to the corresponding validation work packages in WP 2.3. Specific integrating work needed to implement the technologies in the final demonstrator will be conducted in WP2.3.1.

c) **Interactions with Clean Sky 2 ITDs, IADPs, other interfaces**

WP2.2.6 will have an interface with the Systems ITD, mainly in the area of electrical and thermal systems and management, the development and integration of the associated components. It is planned that selected actors from the Systems ITD but also additional partners in the systems sector will contribute.

This WP2.2.6 will also have interfaces to ITD Airframe, Technology Stream A-5: Novel Travel Experience, which addresses generic research studies on novel human centered, ergonomic cabin architectures, linked with augmented reality technologies that enable new immersive services. The generic results achieved in that Technology Stream will be adapted to large passenger aircraft requirements and integrated in the Platform 2 demonstrators.

A systematic interaction respectively entry of intermediate results is planned with currently running national and European funded Research and development programs, and the progressive maturation of selected best candidate concepts and technologies.

As for all other demonstrators, there is a mainline exchange planned with the TE and *Clean Sky 2 Eco-Design* work package to provide relevant results of the integrated flight tests as described in the related chapter.
6.6.3 “Technology Validation” – WP2.3

As stated previously, this second platform of the Large Passenger Aircraft IADP will focus on the development, large scale demonstration and validation of new architectures, concepts and technologies enabling a more efficient integration of structures, systems and cabin. This efficient multidisciplinary integration could result in a major breakthrough in the way aircrafts are designed and manufactured nowadays.

The objective of WP2.3 is to materialise the concepts developed in the “Integrated Product Definition” and provide the means to ensure an efficient, high quality testing of integrated demonstrators. The ambition is to validate multifunctional solutions by means of new multipurpose tests and to prove the manufacturability of the concept in a pre-production environment.

Figure 6.27 – High-level Work Breakdown Structure of “Technology Validation” Work Package
a) Multipurpose Demonstrators – WP2.3.1

WP2.3.1 will materialise the concepts developed in the “Integrated Product Definition” providing the means for designing and manufacturing the large scale demonstrators. Besides the cabin and cargo functional demonstration in WP2.3.1.2, the activities on structural demonstrators will be concentrated in two major areas of the fuselage, the centre fuselage in WP2.3.1.3 and the adjacent sections of a full-scale, full-scope “typical” fuselage in WP2.3.1.1, since these are the ones presenting the largest interface with the installation of relevant systems and with the cabin environment.

For both areas of the fuselage a full demonstration up to TRL 6 will be conducted within Clean Sky 2, although the final configuration of the validation (testing of separated typical and centre fuselage sections or single demonstrator resulting from the assembly of the centre and typical fuselage) will be decided as part of the execution of this project. The need for combining these demonstrators together with the rear end ground based demonstrator developed within the platform one will be analysed. The final decision will depend on the requirements of the multipurpose testing and the complexity of the validation.
WP2.3.1.1 – Next Generation Fuselage, Cabin and Systems Integrated Demonstrator

This work package will be focused on conducting the specific design and manufacturing of the “Innovative Physical Integration Cabin – System – Structure” demonstrator. Therefore, it will consider as an input from WP2.1.2 the final architecture, requirements and specifications. All the detailed design work, tooling definition and manufacturing trials will be conducted here.

Due to the disruptive nature of the solution that is expected to be delivered from the work in WP2.1.2, some of the challenges that the detailed work in WP2.3.1.1 will face are, among others:

- Executing radical and highly integrated structural concepts considering both Cabin and Systems (e.g. innovative integrated sub-components in an optimised build concept)
- Hybrid structures: smart fuselage and component concepts using different material combinations (carbon fibre reinforced plastic and metal or combinations of prepreg, textile and thermoplastic materials)
- Structural load carrying cabin monuments and elements
- Structural load carrying system elements
- Integration of system functions in the structure
- Integration of structure functions in systems
- Optimisation of the attachment of cabin elements in the structure taking into account optimised tolerances
- Customer tailored integration of the structure/systems/cabin

Figure 6.29 - Conceptual representation of the Next Generation Fuselage, Cabin and Systems Integrated Demonstrator

One key milestone to be completed in this work package is the decision gate dealing with the material selection for the Next Generation Fuselage, Cabin and Systems Integrated Demonstrator. A down selection process will be conducted in order to provide mature trade-offs between the currently existing different possibilities: composites and metals. This material selection gate is planned to be conducted prior to TRL 4, and will determine which material or which combination of materials and process technologies are the most promising ones and therefore will be finally considered in the definition of the demonstrator.
In terms of validation, a full scale “multi-purpose” demonstration with large module fuselage section will be conducted in connection to WP2.3.2, extending from the rear Centre Wing Box spar to rear pressure bulk head, and therefore representing all structural, cabin and cargo integration aspects of a “Typical Fuselage”. Associated industrial means as well as new manufacturing and assembly processes will be developed and validated in work package 2.3.3, ensuring their consistency with the global “factory of the future” vision. In order to perform a structural level 3 validation test, the most optimal test configuration (e.g. load introduction, combination with other demonstrators within Clean Sky 2, etc.) will be defined during the execution of the project.
- **Planning roadmap, targeted technology readiness levels**

The top level planning of the activities to be conducted in WP2.3.1.1 is shown in the following roadmap:

- The fuselage structure material down selection (composite vs. metallic vs. best ECOMIX) is planned to take place in 2016, once all supporting studies will be available. TRL 6 will be achieved between 2020 and 2023, depending on the selected technology and the final level of integration.

- **Interactions with Clean Sky 2 ITDs, IADPs, other interfaces**

This work package is responsible for conducting the most visible part of the IADP LPA Platform 2 demonstrator and depends on the results delivered by WP2.1. Further connections to the lower centre fuselage demonstrator and to the rear end demonstrator executed in the IADP LPA Platform 1 will be analysed in order to determine the convenience of conducting common tests.

Besides the interfaces within Clean Sky 2, there are other major interactions of this work package such like:

- Input expected from Lufo V-1\textsuperscript{st} call (Second generation Composite Fibre Reinforced Plastic fuselage) consisting of major enabler technologies at a TRL 4 maturity level. This input is planned to be transferred during the first quarter of 2017;

- Input expected from Lufo V-2\textsuperscript{nd} call consisting on the outcomes of the structural Level 2 fuselage component demonstrator). This input is planned to be transferred during the second quarter of 2018.

**WP2.3.1.2 – Next Generation Cabin-Cargo Functional Demonstrator**

The research within Clean Sky 2 is targeting at step-change technologies that go far beyond current continuous improvement scopes. In order to de-risk the development of those breakthrough architectures and technologies, more time and efforts need to be invested to demonstrate the physical and functional integration of all innovations and to validate that all market needs are met. To cope with this need, this work package shall
develop a full-scale validation and verification platform for concept testing. This platform shall provide a test bench for R&T engineering and proofing the maturity and compatibility of all developed functionalities.

The validation and verification of all individual cabin and cargo specific topics would not be feasible in a single overall multi-purpose demonstrator that combines all fuselage, system and cargo technologies developed, due to time and availability restrictions (see structure test plan).

Therefore, in parallel to the multi-ATA L3 demonstrator described above, an additional and highly flexible cabin and cargo demonstrator will be the basic integration platform, where key cabin and cargo technologies and systems will be integrated, in order to validate and demonstrate at relevant scale and under operational conditions the consistency and seamless interaction of all individual technologies developed.

Tests to be performed shall prove the consistency of the overall architecture principles, the coherency of all combined specific cabin and cargo solutions, as well as the seamless interaction with regard to operational aspects and services. Special focus will be given to securing feasibility and customer acceptance of radical cabin and cargo changes that have significant impact on the aircraft structure and systems. The demonstration platform will thus be the key element for de-risking the development of breakthrough technologies and ensuring the necessary technology readiness.

The demonstration platform shall also be used for testing full cabin passenger services and crew processes in a relevant environment close to reality. For this, a fully equipped cabin as well as a ground handling simulation will be necessary. Also, comfort and user perception tests are in need of a realistic environment to get valid results. Even ground and flight test in real aircraft for full system demonstration will be possibly required.

With regard to novel interface technologies, demonstration of the feasibility of airline network extension to aircraft to support e.g. ground support equipment and systems as well as validation of seamless, cost efficient, always-on and secure communication for multiple users and applications shall be performed. Furthermore the demonstration of an integrated communication approach across different aircraft domains is planned. The feasibility of location based applications and services and the demonstration of a seamless co-existence of IPv6 and IPv4 networks in a dynamic environment shall also be tested.
The scope of work comprises a wide variety of various domains and disciplines, so that the proof of consistency and seamless interaction between all individual technologies is key for all demonstration activities. The fundamental questions to be conclusively answered are as follows:

- **Operation**: How do customers really operate the product and what are their future business drivers – what kind of operations shall be promoted?
- **Services**: What kinds of services will the airlines ask for and what kind of services need to be promoted?
- **Functions**: How can external function/service demands and internally generated functions be mapped to the OEM’s structures?
- **Technologies**: Which novel solution principles and architectures can be introduced into the product breakdown?
- **Integration**: How can integration performance be speeded up, particularly providing evidence of physical and functional integration in much shorter time frame?
- **Industrialization**: How can this be used for improved ramp-up and serial customization performance?

In order to answer above questions, the planned V&V activities will comprise all relevant aspects:

- Cabin & Cargo Performance
- Manufacturing feasibility and readiness
- Manufacturing high volume
- Physical System Integration
- Certification
- Cabin and Cargo Operation tests
- Structure Technologies & Assembling Methods
- Aircraft Integration with disruptive C&C concepts
- Maintenance Operations Solutions & Technologies
- Refurbishing
- Recycling

**Planning roadmap, targeted technology readiness levels**

A next generation aircraft cabin & cargo architecture target concept and the associated requirements developed in WP2.1 will provide the basis of work in WP 2.3.1.2. A subsequent concept definition, preliminary and detailed design of the selected integrated concepts, as mentioned before in this chapter, will deliver pre tested modules to be transferred as inputs to a fully integrated, large scale demonstration in WP2.3.1.1.

The TRL schedule related to the development of the individual selected concepts is again straightforward, as displayed in the graph.
- **Interactions with Clean Sky 2 ITDs, IADPs, other interfaces**

Providing the environment for the cabin and cargo multidisciplinary fuselage structure and systems integrated testing and demonstration, work package WP2.3.1.2 is logically extending the interface with relevant system items in Clean Sky 2.

As outlined before, the target of the demonstration is addressing all key questions related to the integration and assembly of all major and minor systems components. Due to the fully integrated approach, the demonstration is aiming at dealing with systems with primary relevance for cabin and cargo, but also for the principle operation of the entire aircraft.

Beyond contribution from selected actors from the Airframe and Systems ITDs, additional partners in the systems sector will be invited to contribute to the project work package for testing, demonstration and validation of the results.

As for all other demonstrators, there is a mainline exchange planned with the TE and Clean Sky 2 Eco-Design work packages to provide relevant results of the integrated flight tests as described in the related chapter.

**WP2.3.1.3 – Next Generation Lower Fuselage Demonstrator**

The centre fuselage is one of the most challenging large integrated components of an aircraft. With its huge structural complexity, the large number of materials and subcomponents to be combined and connected, and a high density of systems to be incorporated, manufacturing and assembly in industrial scales is an issue of high complexity. In return, it is the one able to largely benefit from higher levels of integration between different principle functions and main aircraft modules. The baseline for this activity will be the development and validation up to TRL6 of a lower centre fuselage section architecture able to materialise both weight and recurring costs savings and compliant with a body landing gear. The architecture studies will be performed following a multidisciplinary approach in order to ensure functional integration between all sub components, systems and landing gear. The associated manufacturing and assembly processes will be developed and validated within this work package, ensuring at the same time its alignment with the “factory of the future” vision.

![Conceptual representations of Next Generation Lower Centre Fuselage](image)

A full-scale validation of the most competitive architecture will be performed in this project. The validation phase will surely require performing fatigue (AFI) tests including pressure, flight and ground cases. A static load case until Ultimate Load will follow, together with a final tear down. The need for conducting additional tests like the
ones linked to Particular Risk Analysis or to the landing gear new developments will be assessed during the execution of the project. The same applies, as already mentioned earlier in this document, to the interest of joining the three major fuselage sections used for demonstration in this project (typical fuselage, centre fuselage and rear end fuselage).

Concerning the product breakdown structure of the demonstration of the centre section fuselage, three scenarios will be assessed during the execution of Clean Sky 2. The final selection will depend on the level of multifunctional integration and on the complexity of the validation:

- **Scenario 1:** One major test comprising Centre Wing Box, Root Joint, Main Landing Gear Bay, Keel Beam, body landing gear attachment and upper shells in order to ensure adequate loading, representativeness and Engineering demonstration needs
- **Scenario 2:** Two major tests. One comprising Joint testing of Main Landing Gear Bay, Keel Beam, body landing gear attachment and upper shells in order to ensure adequate loading, representativeness and Engineering demonstration needs. The other test would include Centre Wing Box and Root Joint
- **Scenario 3:** Several component tests that would lead to Centre Wing Box/Root Joint, Main Landing Gear Bay, Keel Beam being tested independently.
### Planning roadmap, targeted technology readiness levels

The top level planning of the activities to be conducted in WP2.3.1.3 is shown in the following roadmap:

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<td>1 Specification of demonstrator test bed</td>
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<td>2 Detailed design of the demonstrator</td>
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<td>3 Design and manufacturing of tools and rigs</td>
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<td>4 Manufacturing and assembly of the demo modules</td>
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<td>5 Integration of demonstrator modules</td>
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<td>6 Integrated demonstration</td>
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<td>7 Evaluation of results</td>
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| TRL of Next generation lower center fuselage                  | 3    | 4    | 5    | 6    | 6    | 6    | 6    | 6    | 6    |

### Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

The need for combining this demonstrator together with the Next Generation Fuselage, Cabin and Systems Integrated Demonstrator with the rear end ground based demonstrator that is developed within the platform one
will be analysed. The final decision will depend on the requirements of the multipurpose testing and the complexity of the validation.

For the sake of keeping this programme affordable within the constrains resources, developments of technologies with a maturity level lower than TRL 4 might be conducted outside this frame work (e.g. PIA funding framework, CORAC funding framework) and delivered on time for high TRL level validation.

b) **Testing – WP2.3.2**

The objective of WP2.3.2 is to develop, qualify and apply innovative test and measurement technologies for efficient, high quality testing of integrated demonstrators. These new approaches will be underpinned by an understanding of certification requirements that allow a multifunctional test to be used to simultaneously validate an airframe, its systems and cabin. This will have to be enabled by an integrated Multi- Functional Team of Designated Certification Specialists (MFT-DCS) to ensure the suitability of the test methods developed. The plan is to adopt approved test instrumentation, but to also add new technologies such as wireless sensors and virtually assisted tests to the test means. This innovative test equipment paves the way for an integrative approach to testing, where the ensemble of structure, cabin, and system elements are validated, as well as the manufacturing process. The developments will create new levels of adaptability and customisation of the test configurations to allow responsiveness to late maturity of novel or disruptive designs.

![Figure 6.3](image-url)

**Figure 6.36 – WP2.3.2 Work Breakdown Structure (WBS)**
Systematic technology validation on integrated demonstrators requires a strong focus on test programme management, with harmonized processes (test definition and execution) and well-defined interfaces across functions (testing of cabin, system and structure). These approaches will be defined and developed in WP2.1.1 and implemented in the technology validation strategy. The key benefits being sought from an integrated approach to testing are:

- Reduced lead time (and cost) for component validation, leading to earlier entry into service
- Reduced number of individual tests (leaner test pyramid)
- Higher maturity of product at EIS (right first time)
- Improved validation methodology to deliver greater optimisation and earlier/higher maturity leading to improved in-service reliability at EIS

Integrated testing of the product provides high-quality information for operational aspects (prognostics of structural integrity, condition based maintenance, product lifecycle) that could not be obtained by conventional testing and could be used to enhance the airframe utilisation over the longer-term thereby maximising in-service efficiency. This innovative and integrated approach to testing will also bring new challenges:

**Architecture**
- Certification process: Cross ATA technology validation will have to be accepted for certification (via support from the MFT-DCS)
- Definition of requirements for an integrated architecture and its validation

**Organisational**
- Sharing “time slots” between ATAs to implement test activities on the specimen (block test schedule, interleaved schedule or simultaneous testing)
- The timing and synchronisation of the development process for different domains (cabin, system, structure); harmonisation of documentation, organization of new interfaces leading to new ways of working (in parallel) and the inevitable impact on configuration management

**Technical**
- Physical definition of the specimen and test bench has to match the requirements of every stakeholder (physical access, optical access, instrumentation and loading)
- Integration of measuring technologies in a multipurpose demonstrator environment
- Physical definition of the specimen and
- Integration of special equipment for loading and producing suitable environmental conditions
WP2.3.2.1 – Advanced Technologies for Multi-purpose Testing

A new set of technologies is to be developed and matured for use on integrated demonstrators. The main activity in this sub-work package is the adaption of existing technologies and of those developed in WP2.2.1 for the application on large-scale integrated demonstrators. The key objectives of this stream are to enable existing measurement system technology to be applicable across cabin, system and structural domains. The following techniques will be developed and transversely integrated with a high priority.

- **Acoustic methods**
  For advanced structural monitoring during testing (crack propagation, early warning of damage and failure) will be extended to the domains of cabin and systems for noise monitoring (cabin comfort) and flaw identification during testing. Applicability could extend from manufacturing quality checks to ground vibration testing and in-flight testing, yielding applications such as interior and exterior noise localisation.

- **Thermal methods**
  Offer great potential for transverse application in structural, cabin and system areas. Thermo-elastic Stress Analysis (TSA) developed in WP2.2.1, will be used for the early detection of critical spots, to provide real data for structural optimisation early in the fatigue test cycle with the result of providing early design maturity. These techniques will be directly applied across domains for thermal sensing, where they are well suited for the identification of temperature critical areas on cabin and system elements.

- **Optical measurement methods**
  Techniques such as digital image correlation and strain-sensitive coatings offer full field strain and deformation measurements, allowing for extended calibration of numerical simulations and early identification of high stress areas. Extension of these techniques to all new load carrying elements (cabin & systems) will provide a
comprehensive understanding of the integrated specimen behaviour.

- **Optical fibres for strain and temperature measurements**
  This technology offers semi-full field strain data with high accuracy and can even be directly integrated into the airframe and cabin parts, with the promising perspective of structural health monitoring, possibly even in-flight. Another application during multipurpose testing and in-service would be continuous temperature monitoring, e.g. along wires, pipes and systems installation with the same device.

- **Integration and extension of data correlation tools on large scale models (output from WP2.2.1)**
  Automated live data correlation enables fast decision making of multi-functional teams during integrated tests, which is a precondition for simultaneous monitoring of multiple kinds of parameters.
  The benefits of implementing and validating those technologies on an integrated multipurpose demonstrator are threefold:
  - **Significant lead time reduction**, by better understanding the aircraft behaviour (early maturity of design), anticipation of showstoppers (unexpected early failures) and unexpected maintenance.
  - **Airframe optimisation** by extended monitoring technologies (optical, thermal, acoustic, full-field methods), leading to **weight reduction** (less overdesign and better management of reserve factors across interfaced elements and systems)
  - **Overall cost reduction**, brought by the use of multipurpose technologies, rendering the overall test campaign cheaper by having one technology monitoring several aspects.

There is a statistical advantage provided by the use of data rich non-contact methods in that the high data density gives an increased reliability of the measured data (due to a large sample size) and which can match those produced by computational techniques. This leads to a robust and more complete validation of the simulation. These novel technologies will also extend beyond the multipurpose demonstrator testing, bringing added values to other areas such as Structural Health Monitoring and in-service inspection to reduce the cost of operation by faster inspection and service life determination.

**WP2.3.2.2 – Multi-purpose test facilities**

A multi-purpose test facility will provide a novel platform on which to validate the novel and integrated demonstrators developed in *Clean Sky 2* across all the relevant ATAs. The scope of this work programme therefore requires a move away from the traditional and inflexible large steel structural test rig, which imposes the need to freeze the test specimen configuration before the test fixture design can be properly started. The objective of this work package will be to develop the test hardware which provides the ‘input conditions’ in a way that allows maximum, if not total flexibility, therefore allowing the design and development of the demonstrator to continue for the greatest time allowed in the development programme.

This will require an increase level of cooperation and synchronisation between the Demonstrator development and Test work streams which is a new approach in this aspect of the aircraft development cycle and will establish a new state of the art set of capabilities in aircraft testing. Test configuration development will follow the development of the airframe, system and cabin demonstrator concepts (WP2.3.1) in a parallel stream providing a generic test capability, which will be tuned or tailored in the final stages to suit the specific dimensions and requirements of the test specimen. This high level of integration across work packages will ensure that the
requirements defined in WP2.1 are continually assessed, manifested and properly implemented in WP2.3.1 and WP2.3.2.

For the objectives set out above to be met the test hardware must satisfy one key criterion in order to be for the purpose of testing the integrated demonstrator, which is that it is a flexible/adaptable load input system for easy reconfiguration and therefore adaptation to late changes in design resulting from the late development of novel concepts or unexpected disruptive ideas. By following this approach the utility of a large research programme can be maximised and ensure that the end result is as close to the state of the art and not so old as to be obsolete at the end of the programme.

Of primary importance in the development of the test hardware is that the technologies considered are able to meet the challenging requirements for speed of implementation and adaptability and for this purpose new ideas for generating load inputs or environmental conditions must be considered. The criteria that should be considered of relevance to the test hardware development can be placed into two groups:

**Loading and environmental conditions – inputs**

- Integrate heating/cooling (by use of induction, halogen lamps, liquid nitrogen) - environmental conditions to closer simulate flight situations
- Versatile loading procedures for static and dynamic tests (e.g. robotic loading)
- Generic rig hardware standard joints and beams

**Sensing and data recording – outputs**

- Amenable also to the technologies developed in WP2.3.2.1
- Automated or on-line inspections during tests
- Flexible and low cost metrology systems for deformation measurements that are integrated into the loading hardware
- Non-contact and wireless systems for ease and speed of setup and minimal interference with other test requirements

In all cases where this new testing approach is used the underlying requirement is that all parties must be able to access the demonstrator and be able to capture relevant data either with independent equipment or multi-functional sensors. Furthermore consideration should be given to Structural Health Monitoring systems integrated into the component that could be used as one of the primary sources of data output.

**WP2.3.2.3 – Test performance**

Test performance will be the final stage of the whole process in which all the elements developed in Platform 2 will be brought together, implemented and validated. To ensure the efficient execution of this final stage the novel technological and organisational approaches need to have a high level of maturity, ensuring that the test process will be performed in accordance with a ‘right first time’ philosophy. A lean test pyramid will be defined and implemented in phases so as to minimise the physical effort and sheer quantity of deliverables required to
support the final demonstrator, helping to achieve the whole test programme within the time and cost constraints of the Platform 2 project.

Satisfactory execution will rely on the following elements having been robustly achieved in the lead up to test phase of the programme:

1. A phased approach to the definition of the test pyramid so that higher resolution of test requirements is achieved over time
2. Clear definition and implementation of the lines of communication, particularly between ATAs, by setting up of a virtual/physical plateau for all multi-purpose test demonstrators with one coordinating entity
3. Definition of the access plan and instrument interfaces and test schedule methodology
4. Dry runs and process simulation of test process
5. Large scale integrated demonstrator test execution

The test pyramid that is to be defined will necessarily be lean so as to minimise the physical effort and sheer quantity of deliverables required to be achieved within the time and cost constraints providing greater effectiveness and efficiency of the test programmes. Allied to this the existing test processes (for all ATAs) will be harmonized and will exploit the existing maturity of the test process methodology in structural, cabin and system tests that deliver data with the quality and integrity required for certification. Extending these processes so that they are applicable to a multipurpose or integrated test will be a required first step before they are harmonised to allow their implementation on the demonstrator validation.

Ensuring that the certification requirements are considered at an early stage is a key enabler in the test process design and development. This must be done by collecting certification requirements from WP2.1 and WP2.2 via the MFT-DCS. This in turn will ensure that by design the test methods are suited to meet future certification needs. This anticipation in the development of Multi-Functional Testing under the guidance of the MFT-DCS supports the idea this novel approach will be able to progress into industrial use.

The major innovation in this work package will be the development of the approach for integrated testing where the schedule for the different ATAs and their access to the specimen will be defined. The options are for time slots to be allocated as blocks, interleaved time slices or simultaneous testing. The result that is required is to determine which approach yields the most efficient and effective use of time at the lowest cost, as well as minimising the risk of delays or downtime of the test.

Considering a more technical aspect there is a further requirement to establish a system and structure of information exchange between the various communities to allow the accurate monitoring of progress and development of a large test. That system should include the ability to identify any changes and to obtain requirement and validation from the right personnel located near to or remote from the test. This must be integrated with the implementation of data analysis methods developed in WP2 and WP3 for the efficient comparison to and evaluation of the numerical predictions.

The overall outcome of this task will provide physical validation not only of the integrated specimen but also the development process, associated documentation, configuration management and the proposed certification
process and workflow with its associated company organization to ensure appropriate skills are available to execute further integrated tests for future aircraft programmes.

c) “Pre-production lines” – WP2.3.3

Nowadays, in the aerospace industry it is common to use the very beginning of the serial production to mature the end-to-end process. This way of doing has a huge detrimental effect on the learning curve: high additional investment, high level of Recurring Costs for a longer than planned period, difficult ramp-up, etc. This delays dramatically the return on investment and jeopardizes the programme business profitability. In mass-production industries like Automotive, pre-production lines are used since a long time. Full Industrial system is tested and fine-tuned for thousand units’ production before being copied and pasted for full rate series.

As explained in the introduction to this joint industry programme, the key relevance of the Clean Sky programme is not only to develop and mature complex, highly innovative technologies through large demonstrators in realistic operational condition, but also explore and develop the technologies to manufacture and assemble these innovative technologies in an industrial environment, which is the key part to turn innovations into industrial leadership. Therefore in the LPA IADP, the manufacturing and assembly processes associated to the deployment in a realistic industrial environment are an inevitable requirement. For the next generation large passenger aircraft integrated fuselage-cabin-cargo-system concept this realistic environment is the firm principle proof that the manufacturing and assembly of these highly complex, integrated large modules is possible, and can also be achieved for the potentially required high production rates.

Pre-production lines aim at validating new production concepts and ensuring that technologies are tested against the real complexity of an industrial environment. It is important to highlight that Pre-production lines are a fundamental stream of the whole Future of Aircraft Factory vision. The whole picture includes smart tools for the shop floor, augmented/virtual reality for mediated workers, collaborative robots and full virtual production testing among others.

In this work package, the key aspects of a potential industrialisation are examined and associated methods, tools and processes are developed in parallel to WP2.2 and WP2.3.1, where a combination of critical technologies for a next generation fuselage-cabin-cargo concept is developed and demonstrated for representative large scale, highly integrated modules.

- **Demonstration Objectives**

With a number of important subsequent improvements, the current concept of fuselage manufacturing and assembly is virtually separated from the inclusion of the fuselage interior. An essential part of the assembly production follows a sequential line of steps. With the targeted much higher level of physical integration and due to the approach of a “cross ATA-chapter” design of structural components and functional hardware, the assembly process have to be substantially re-thought. A high degree of automation, the application of “green” principles in production and manufacturing processes at high productivity and efficiency are the targeted results of WP2.3.3, thus providing the added value versus the current state of the art. Pre-production lines will be used as pilot lines
for maturity demonstration gate to integrate all new technology bricks. Industrial process capability will be ensured through knowledge acquisition and the following advantages:

- Single entry point of new technology implementation
- Robust cost assessment (real labour time, real hourly rates)
- Machines and tooling capability demonstration
- Robust Cpk assessment
- Process standardization ensured for key components
- Shop Floor infrastructure and reconfigurability of the workshop
- Complete the industrial V&V
- Key supply chain elements validation
- Overall Equipment Efficiency calculation for key Capital Expenditure mitigation
- Skills and learning opportunity (blue & white collars)
- Acceleration of the learning curve
- Potential support to cut-over with serial production
- Home for test articles (to avoid serial production disruption)
- Give access to Quality for anticipation of the Quality Assurance

Based on the next generation integrated fuselage concept as developed in work package WP2.1 and materialised in WP2.3.1, the target of work package WP2.3.3 is to develop and demonstrate the critical “differentiating” process elements in both assembly and manufacturing. Key demonstration activities will be:

- Development and qualification of principle production steps and processes for key parts and components
- Design and principle testing of special tooling
- Development and testing of advanced manufacturing processes
- Development and testing of assembly processes, including the development of the required tooling
- Application / accomplishment of compliance with Eco-Design principles, related use of materials, resources, deployment of processes
- Adaptation, development and qualification of test and measurement means for quality control and quality assurance
• Virtual demonstration through a combination of key physical and simulated assembly and manufacturing processes to manufacture and assemble the next generation aircraft integrated fuselage.
• Definition and principle testing of key manufacturing steps for key components for the center fuselage
• Definition of an integrated assembly concept for the lower center fuselage at high rates, definition of key components and subassemblies, in particular the main landing gear
• Review of automation capabilities, potential deployment of robotics
• Definition and test of key tools and processes
• Development and qualification of related test and measurement means for quality control and quality assurance
• Eco-efficient production processes

The breakdown of WP2.3.3 is tailored straightforward to account for the “future factory” needs for the next generation aircraft “typical fuselage” – highly integrated with all associate cabin and cargo modules and systems in WP2.3.3.1, and the centre fuselage in WP2.3.3.3.

WP2.3.3.2 is addressing Major Component Assemblies (MCA), which are important items in the industrialisation in particular for potential work sharing between cooperating partners.

Figure 6.39 – WP2.3.3 Principle Work Breakdown Structure (WBS)

- **Planning roadmap, targeted technology readiness levels**

Even though running time-wise in parallel, work package WP2.3.3 is gradually including essential information from work packages WP2.1 and WP2.2.3 from the start until the end. As in principle laid out in WP2.1 and WP2.2, the work plan in WP2.3.3 will include and integrate a number of best candidate intermediate future factory concepts emerging from currently on-going Research Programs to be selected at the end of 2014 and early 2015.
It is important to note that the activities in WP2.3.3 shall be conducted concurrently to the preparation of the large scale demonstration in WP2.3.1.

As explained before a fully exploited future factory concept shall be delivered as intermediate result with a direct link into WP2.1.3 (Value assessment), in the second semester of 2019.

The TRL schedule is determined by the development path of the major demonstrators described in WP2.3.1. The activities conducted in Pre-production lines will enable the true validation of TRL6 maturity level of the final configurations.

- **Interactions with Clean Sky 2 ITDs, IADPs, other interfaces**

Interfaces with the Airframe ITD are planned addressing all key questions related to the integration and assembly of all major and minor components.

With the large variety of production related research and technology development to be addressed in WP2.3.3, a substantial amount of work is intended to be offered to small, medium and large partners. Airbus in its role of airframe integrator is targeting to take a coordinating role in all work packages.

In this course, a systematic interaction respectively entry of intermediate results is planned with currently running national and European funded Research and development programs, and the progressive maturation of selected best candidate concepts and technologies. It is planned that core partners and Call for proposal partners in the European structure and systems supplier sector will be specifically invited to join the project on subjects of material development and processing, manufacturing systems, and test rig equipment.

As for all other demonstrators, there is a mainline exchange planned with the TE and *Clean Sky 2* Eco-Design work packages to provide relevant results of the integrated flight tests as described in the related chapter.
6.6.4 “Summary of Platform 2 large scale demonstrators and overall work share provisions

In general, in Platform 2, Airbus has the ambition to take a strong, leading integrator role, but also to include major capable actors from the European aeronautical industrial community to take substantial shares R&T and development work – and the related responsibilities in the project. A first batch of initial Core-Partners is planned to be selected before the start of the project, the majority of Core-Partners will be selected in subsequent calls in the first three years of the Clean Sky 2 runtime. A significant amount of smaller, well identified topics is planned to be offered to further partners through call for proposals. The overall partition of work shares may be close to 30% / 40% / 30% (Clean Sky 2 Launching Industries/Core-Partners/CfP Partners).

Platform 2 Budget provisions and synthesis of added value with respect to H2020 targets

Aligned to the concept of this document, namely to associate provisional gross budget figures to the main technology demonstrations, these values will be provided synthesized for Platform 2 assigned to the three large scale integrated demonstrators:

D2.1 Next generation fuselage, cabin and systems integrated demonstrator (WP2.3.1.1)
D2.2 Next generation Cabin-Cargo functional demonstrator (WP2.3.1.2)
D2.3 Next Generation lower centre fuselage demonstrator (WP2.3.1.3)

There will be no explicit cost breakdown provided by work package for Platform 2 as part of this document.

The same approach is used with respect to the added values of technologies respectively demonstrators in Platform with respect to Horizon 2020 targets, as the activities in the work packages do typically contribute to the development of technologies to be integrated at the main demonstrators, or to increase the level of maturity (“TRL”).
## 6.6.5 Synthesis of added value with respect to H2020 targets

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Completed by</th>
<th>Lead actor / key contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D2.1: Next generation fuselage, cabin and systems integrated demonstrator (WP2.3.1.1)</strong></td>
<td>Advanced fuselage architecture fully integrated next generation cabin &amp; cargo concepts and systems</td>
<td>CO2: -5 to -8% (combined with D2.2.1)</td>
<td>Green operation, Cost of operation, community noise, passenger comfort</td>
<td>Reduce dependency on fuel price</td>
<td>2020</td>
<td>Airbus CS2 leaders Core &amp; CfP partners</td>
</tr>
<tr>
<td><strong>D2.2: Next generation Cabin-Cargo functional demonstrator (WP2.3.1.2)</strong></td>
<td>Cabin functionalities, advanced networks for energy and data transfer</td>
<td>CO2: -7 to -11%</td>
<td>Passenger comfort, Customer value</td>
<td>Travelspace = workspace</td>
<td>2020</td>
<td>Airbus CS2 leaders Core &amp; CfP partners</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n/a</td>
<td>Passenger comfort, Customer value</td>
<td>Reduction of turn around time</td>
<td>2020</td>
<td>Airbus CS2 leaders Core &amp; CfP partners</td>
</tr>
<tr>
<td></td>
<td>Assembly of parts at MCA and FAL (structure, cabin, system installation)</td>
<td>Green materials and processes</td>
<td>Cost of production</td>
<td></td>
<td>2020</td>
<td>Airbus CS2 leaders Core &amp; CfP partners</td>
</tr>
<tr>
<td></td>
<td>Cross „ATA“ synergetic functional design. Fully integrated MDO concept</td>
<td>CO2: -3 to 5%</td>
<td>Green operation, cost of production, green lifecycle</td>
<td></td>
<td>2020</td>
<td>Airbus/ Dassault CS2 leaders Core &amp; CfP partners</td>
</tr>
<tr>
<td></td>
<td>Efficient management and use of energy</td>
<td>CO2: -2 to 3%</td>
<td>Green operation</td>
<td></td>
<td>2020</td>
<td>Airbus/ Dassault CS2 leaders Core &amp; CfP partners</td>
</tr>
<tr>
<td></td>
<td>Use of multifunctional material, MRO concepts, failure modes</td>
<td>CO2: -2 to -3%</td>
<td>Green operation, green lifecycle</td>
<td></td>
<td>2020</td>
<td>Airbus CS2 leaders Core &amp; CfP partners</td>
</tr>
<tr>
<td><strong>Next Generation lower centre fuselage demonstrator (WP2.3.1.3)</strong></td>
<td>Advanced fuselage structure fully integrated the next generation wing and main landing gear concept</td>
<td>CO2: -5 to -8% (combined with D2.2.2)</td>
<td>Green operation, Cost of operation, community noise, passenger comfort</td>
<td>Reduce dependency on fuel price</td>
<td>2020</td>
<td>Airbus CS2 leaders Core &amp; CfP partners</td>
</tr>
</tbody>
</table>

*Core-Partners: Large & medium industry aerostructures, supplies cabin & cargo system and equipment;  **CfP-Partners: SME’s for systems, equipment, IT-communication, RE’s, Academia*
6.7 Platform 3 “Next Generation Aircraft Systems, Cockpit and Avionics”

6.7.1 Introduction

6.7.1.1 Challenges for the next generation LPA cockpit and avionics

Large Passenger Aircraft market remains highly competitive, and beyond the long lasting duopoly between US and European manufacturers, new entrants are coming: for some of them, although they cannot pretend immediately to a significant market share, they have means to catch up rapidly and reach a technology level comparable to legacy US and European airframers, and potentially support their ambition with both a captive “home” market and low costs and pricing.

This is why European LPA shall stay ahead of any type of competition, in particular for cockpit and avionics, which had been a key differentiation and thus a success factor for the current European LPA families.

The mid to long term vision that allows to build such ambition for cockpit and avionics is to prepare the technologies that would allow for significant step changes, in particular for simplification of the operation of the aircraft and therefore to deal with:

- increasing complexity of the aircraft and its own systems (driven by need for performance and vehicle optimization), in particular in abnormal or adverse conditions,
- increasing complexity of the Air Transport System as a whole, and of ATM in particular,
- increasing heterogeneity of crew population (diversity of experiences, level of trainings, cultural background…) and of their operational environment (type of carriers with or without own legacy, type of network and routes, etc).

While

- ensuring high safety level,
- supporting the growth of fleet and of global traffic (ref : Mobility objectives),
- providing operators with solutions for economic benefits such as to
  - enable flexibility of operations (thanks to levers for optimization) – e.g. trajectory optimization depending on multiple criteria, including ad hoc “green” optimization (Fuel and subsequent emissions) pending operator’s own policy,
  - minimize disruption of service (failure, weather, …),
  - provide sound answers to disruptive (or provocative) “expectations” from some operators (notably Low Cost Carriers),
  - connect aircraft to all operations,
  - reduce time to market with affordable new functionalities,
  - support high level of integration of innovative features, in particular in smaller cockpits,
  - master the costs of the systems (acquisition and operation).

On cockpit and avionics, one specific piece of context is created by the enormous progress in computer technology, miniaturization of electronics, computer aided or computer controlled functions, innovative man-machine interface (notably personal consumers electronics and communications). This creates both:

- expectations and appetite from operators for “best in class” technologies,
- opportunities in functionality, in performance, in size, in mass, in cost,
• challenges to adapt such technologies to aerospace constraints and to leverage benefits in the individual technologies into major combined advantage at the aircraft level,
• innovations have to be combined with new capabilities and functionalities of future ATM operational procedures, with the requirements for integration in a next generation cockpit, and with the potential evolution of the crew role (workload, task distribution, etc.).

Addressing such challenges by targeting ambitious, and ultimately disruptive, solutions will maintain leadership for European industry, more specifically airframers’ lead in conception and design for cockpit and flight operations. Incremental developments could also profit from spin-offs from such mid to long term roadmap.

6.7.1.2 Historical context and ambition within Clean Sky 2

Since the past decades, the cockpit for large passenger aircrafts design has evolved with the constant objective to reduce the pilots’ workload while keeping high safety level.

For the A320 cockpit, a step change has been made with the introduction of the side stick. Also the integration of the displays has been a significant modification; the systems command being not yet integrated. Incremental improvements have been made for the A380 and A350 cockpits with the introduction of displays interactivity (KCCU) and the integration of some of the systems commands. The future deployment of SESAR will also reduce the pilot workload with innovative ATM operational procedures.

Figure 6.36 – Airbus cockpits evolution
6.7.1.2.1 The Disruptive Cockpit ambition

The next step change expected for the cockpit of the future LPA aircraft will include innovations such as:

- continuous auto-pilot, available in any flight condition. This will significantly reduce the pilot workload for high-demanding tasks,
- systems management improvement,
- mission management systems to support aircraft navigation, helping to manage diversions for example,
- aircraft status, pilot health and behaviour monitoring. Technologies such as eye-trackers can greatly support this function,
- more intuitive interfaces (e.g. tactile) allowing the integration of all commands and displays,
- augmented vision system (SVS/EVS) with head-up and/or head-down displays.

Another expected step change in the future cockpit is the increase of the communication with the ground. Progress on speech recognition should allow displaying messages to the crew for example. It is anticipated that Airline Operating Centres could support the flying crew to manage the mission and possibly the systems, if adequate communication is provided.

Our ambition is therefore to work on several concepts, all impacting the crew role: the way they are operating the aircraft and the way they should manage challenges. These concepts are worked-out in other programme frameworks up to a certain level of demonstration (TRL 4 maturity). In Clean Sky 2, the ambition is to transfer the most promising disruptive cockpit concept from national funding programme and to build a highly representative ground demonstrator of the future cockpit for large commercial aircraft. This ground demonstrator, so called “disruptive cockpit”, includes LPA future cockpit functional organisation, cockpit design, the way the crew is operating the aircraft both in usual and adverse situations, and hardware in the loop to have representative equipment, when relevant. Specific flight tests will complete the ground demonstrator when flight environment is
required. The ambition is to reach a TRL 5 level of maturity for this disruptive cockpit within the Clean Sky 2 IADP LPA Platform 3.

The Disruptive Cockpit concept takes place in an Air Transport System (ATS) as defined by SESAR: airspace is flexible, imposing few constraints on trajectory management. Moreover, it is anticipated that the whole ATS is more connected, enabling a stronger cooperation between the Air Traffic Control (ATC) and the Airline Operational Centre (AOC); in turn these two are providing an increased support to the flying crew. This is the landscape in which the proposed Clean Sky 2 activities are done.

The primary objective of the Disruptive Cockpit concept is to bring the workload and required skills of a crew in abnormal situation closer to those in normal situation. The first benefit is the increase of safety margins thanks to less challenging environment in abnormal situations. Reduction of training needs is an additional benefit, both in term of crew training cost and of an alleviation of the potential future shortage of pilots.

A direct consequence of this objective and the foreseen SESAR consequences (increased ground support) are a significant challenge of the work sharing between the Pilot Flying, the Pilot Monitoring, The ATC, the Airline dispatcher and the ground and board systems.

The Disruptive Cockpit ambition within the LPA platform 3 is summarized in figure 6.39.

6.7.1.2.2 The Enhanced Cockpit ambition

Besides preparing a step change in cockpit concept, new technologies could make their way toward existing large passengers’ aircraft. The corresponding cockpit is identified as “Enhanced Cockpit”. The ambition for the cockpits of LPA (both Enhanced and Disruptive) is summarized in figure 6.39. Although LPA Cockpit demonstration is driven towards Airbus-like aircrafts, involvement of other European airframers is leveraging some opportunities, be it on some specific technologies or on challenging requirements that can be profitable to LPA. Possible synergies between business jet or regional aircraft and LPA are therefore also depicted in figure 6.39.

On bizjets the ambition is to introduce incremental but significant innovations in terms of navigation, sensors and Man Machine Interface (MMI), in existing cockpit concepts. Enabling technologies are largely the same as those required for next generation LPA, with however some specificities, and with an analysis of integration and an assessment of installed performances which will be specific to the operations of bizjets. The studies will typically start at TRL 3 to 4 with the analysis of the intended functions and elaboration of operational concepts, continue with integration and simulations based on evolution of cockpit demonstrators, and when necessary lead to flight tests of elementary technologies.
### 6.7.1.2.3 The architect-integrator role

Compared to other demonstration frameworks, the ambition of the IADP LPA platform 3, focusing on cockpit demonstration, is to leverage the architect and integrator role of the airframer(s) across the aerospace community. The architect and integrator role of the airframer(s) in flight operations and cockpit concept/design is predominant. This encompasses various dimensions in multidisciplinary types of solutions integrated at aircraft level:

- Designing the way to operate the aircraft is highly dependent on the vehicle characteristics. Example: flight dynamics and performance,
- Functional architecture and design of the functions must be addressed with the complete functional scope. Example: systems management, warning and alerting functions need a comprehensive mastering of the full functional chain,
- Physical integration in the aircraft is by construction highly dependent on the airframe design and constraints/opportunities to optimize the solutions,
- Mastering the technology and supporting technology enablers for development up to certification and in service support needs to be performed in an end-to-end approach. Conversely, in-service experience of events occurring in airlines operation is feeding the design.

<table>
<thead>
<tr>
<th>Function</th>
<th>Ambition for Disruptive Cockpit</th>
<th>Ambition for Enhanced Cockpit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FLY</strong></td>
<td>Autopilot &amp; auto land &quot;anytime / any conditions&quot;; adapted controls</td>
<td>Enhanced auto-pilot robustness</td>
</tr>
<tr>
<td><strong>NAVIGATE</strong></td>
<td>Support to manage abnormal missions</td>
<td>Approach: noise management and stabilization monitoring</td>
</tr>
<tr>
<td><strong>COMMUNICATE</strong></td>
<td>Voice to System</td>
<td>In-flight separation</td>
</tr>
<tr>
<td><strong>MANAGE SYSTEMS</strong></td>
<td>Support to manage un prescribe cases</td>
<td>Dual Frequency Multi Constellation GNSS (DFMC)</td>
</tr>
<tr>
<td><strong>MONITOR ENVIRONMENT</strong></td>
<td>Incapacitation detection and management</td>
<td>Voice command recognition in all cockpit noise conditions, Flexible Communication</td>
</tr>
<tr>
<td><strong>MONITOR CREW</strong></td>
<td>Fatigue management</td>
<td>Functions for efficient and easy systems management</td>
</tr>
<tr>
<td><strong>OPERATIONAL CONCEPT</strong></td>
<td>Collision avoidance on ground</td>
<td>Automatic failure reconfiguration system</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concept</th>
<th>Large Passenger Aircraft (LPA)</th>
<th>LPA / Business Jet synergies</th>
<th>LPA / Regional Aircraft synergies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FLY controls</strong></td>
<td>Controls adapted to the new concept</td>
<td>Approach: noise management and stabilization monitoring</td>
<td></td>
</tr>
<tr>
<td><strong>NAVIGATION sensors</strong></td>
<td>Breakthrough in availability</td>
<td>In-flight separation</td>
<td></td>
</tr>
<tr>
<td><strong>MISSION MANAGEMENT</strong></td>
<td>Distributed mission management system (data base and performance servers)</td>
<td>Dual Frequency Multi Constellation GNSS evolution and integration</td>
<td></td>
</tr>
<tr>
<td><strong>INTERACTIVITY on DISPLAYS</strong></td>
<td>High integrity touch-screen (CDS &amp; control panels)</td>
<td>Enhanced visor data fusion for improvement situation awareness</td>
<td></td>
</tr>
<tr>
<td><strong>AUGMENTED EXTERNAL VISION</strong></td>
<td>See through Skin?</td>
<td>Touch-screens on limited applications</td>
<td></td>
</tr>
<tr>
<td><strong>AVIONICS</strong></td>
<td>Ability to support disruptive functions</td>
<td>Touch-screens on limited applications</td>
<td></td>
</tr>
<tr>
<td><strong>M&amp;T</strong></td>
<td>Unified Models Based Systems Engineering for the cockpit</td>
<td>Multi-modality voice command</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6.39** – Ambition summary for the Disruptive and the Enhanced LPA cockpits. Possible synergies between business jet or regional aircraft and LPA are also shown. N.B.: Several technologies feeding the ambitions are prepared in other frameworks (refer to chapter 6.7.2.5)
6.7.2 IADP LPA Platform 3 presentation

6.7.2.1 Strategy and key milestones

The ultimate objective of platform 3 is to build a highly representative ground demonstrator to validate the Disruptive Cockpit concept by 2023 to be ready for a possible launch of a future European LPA aircraft. Aiming at a ground demonstrator as final target before handing-over the technology to a development program is unusual. Conclusion of a research activity in aeronautics is usually materialized by flight tests. In the case of a cockpit concept, thanks to enhanced simulation capabilities, the need for flight test can be alleviated. A whole cockpit in a simulated ATS environment will provide better efficiency and value for cost. The work sharing adequacy between the crew and the systems and within the crew can be assessed on ground. Furthermore, suitability of functions allocation within the systems and the layout of the cockpit as well as of function of each system can be also evaluated on ground. Nevertheless, some key technologies need flying environment (the auto-pilot for example) as an essential step in the validation process but not as an end.

Most of the components of the ground demonstrator will be simulated. Integrating real equipment will be done only when this adds a significant value: either to ensure the validation of the disruptive cockpit concept or to check that individual technologies can be properly integrated in a LPA cockpit.

Although the Disruptive Cockpit is the main target of LPA platform 3, some of the technologies that will be worked out may find an earlier application. These technologies spin-offs would be candidate for an incremental development of the existing family of commercial airplanes. These technologies will be declared successful only if they are fully integrated together with the operational concept and organisation of current state of the art cockpits. Such integration platform is identified as an “Enhanced Cockpit” here below.

![Figure 6.40 – Platform 3 LPA Cockpits key milestones towards full Disruptive Cockpit (DisCo) demonstration](image-url)
Intermediate key steps have been therefore defined within the LPA platform 3 to ensure the Disruptive Cockpit demonstration success:

- **PHASE 1: Generic technologies and avionic functions development – 1st wave**
  First phase is the development of innovative avionic functions and technologies up to a TRL 4 by 2018. Within the highly innovative cockpit domain, a single cockpit function can consider several technology solutions. The objective is therefore to develop, within the IADP LPA platform 3 WP3.1 and WP3.2, the avionic functions and technologies that cannot be transferred from other platforms or projects. These activities will be performed in collaboration with several key systems suppliers as well as with other airframers (business jet and regional aircraft). Involvement of other European airframers will allow for leveraging the results on case by case basis.

- **GATE 1: Decision to demonstrate integration of some technologies into the Enhanced Cockpit**
  A decision gate beginning 2018 has the objectives to:
  - Verify technologies maturity,
  - State on the relevance of the integration of such technology in the Enhanced Cockpit,
  - State on the relevance of a fully integrated demonstration for the validation of the technology or on stand-alone demonstrations.

- **PHASE 2-a: Customization and integration of some technologies into the enhanced cockpit**
  This second phase consists in the integration and validation on a case by case basis of some of the innovative functions and technologies developed in step 1 or transferred from other platforms and projects into the Enhanced Cockpit of the state of the art LPA legacy aircraft (WP3.4).
  The selected functions and technologies will be customized for this enhanced cockpit prior to be integrated with on board architecture enabling these functions to be operated in realistic environment (WP3.4). The purpose of such highly representative ground demonstration is a fast ramp-up of most promising functions and technologies into the LPA legacy fleet. Such intermediate demonstration will foster knowledge allowing fine tuning of the functions and technologies specifications for the future Disruptive Cockpit demonstration.

- **PHASE 2-b: Generic technologies and avionic functions development – 2nd wave and flight testing**
  In parallel to the integration of some technologies into the Enhanced Cockpit, further development of innovative functions and technologies are foreseen based on results of the first development wave. To that end, refine specifications will be provided to key systems suppliers. These activities will be hosted in WP3.1 and WP3.2.
  Specific flight tests will be performed on some functions and technologies developed in platform 3 or transferred from the ITD Systems where flight environment is mandatory to reach TRL 6 maturity level (WP3.3). These activities will be performed in collaboration with several key systems suppliers as well as with other airframers (business jet and regional aircraft). Involvement of other European airframers will allow for leveraging the results on case by case basis.

- **GATE 2: Disruptive Cockpit transfer from national funding programme**
  National funding projects should deliver a disruptive cockpit concept at a TRL 4 by 2020. From a clean Sky 2 perspective, this decision gate will validate the most suitable target for the following phases.
• **PHASE 3: Customization and integration of technologies into the disruptive cockpit**
  The third phase is the transfer of the disruptive concept (brought to a TRL 4 in national funding framework) to the CS2 LPA platform 3 as well as the selection, customization and integration of innovative functions and avionics technology bricks (from WP3.1, 3.2 of CS2 LPA, and from other frameworks including CS2 ITD Systems WP1) into the LPA Disruptive Cockpit demonstration (WP3.5). Additional LPA airframer key technologies essential to the overall product differentiation strategy will be also integrated.

• **GATE 3: Disruptive Cockpit demonstration decision gate**
  A decision gate scheduled in 2021 will trigger the Disruptive Cockpit demonstration specific testing activities.

• **PHASE 4: Customization and integration of technologies into the Disruptive Cockpit**
  A highly representative Disruptive Cockpit ground demonstrator will be built-up to validate the disruptive concept. The cockpit being not limited to an addition of equipment but the place where the crew is operating, the evolvement of the crew role is a key objective in platform 3. The on board/on ground interactions and the crew acceptability will be therefore also demonstrated. The concept will be validated against the accrued experience of in-service operations and training; it will be checked that an airplane with such a concept can be certified. The validation will rely on test pilots qualified to assess operational concept, on flight instructors experienced in rating airline pilots and on engineers qualified in human factors assessment. The preparation of the certification of the disruptive cockpit will be also part of this phase. The identification of possible impact of this new concept to the regulation and the determination of possible means of compliance will be studied. A TRL 5 level of maturity of the Disruptive Cockpit is expected in 2022.

Platform 3 will also address the key maintenance activities initially foreseen for the former EU Level 2 Project VITALS - Value Chain Improvement through Airline Integrated Maintenance Technologies and Services (WP3.6). The key objectives addressed are to enhance the reliability and affordability of the air transport system through less operational disruptions, increased asset utilization and higher maintenance economics efficiency. The demonstration will be provided on the basis of a multidisciplinary integration of aircraft and ground based health monitoring and management and maintenance supporting technologies into a service oriented, operational focused, collaborative environment.
6.7.2.2 IADP LPA Platform 3 Setup and activities

Platform 3 is made of 7 work packages:

- WP3.0 is dedicated to project management activities,
- WP3.1 and WP3.2 are hosting the development of innovative avionic functions and technologies complementary to ITD Systems and other funding programmes,
- WP3.3 is dedicated to flight test for functions and technologies where flight environment is of paramount importance,
- WP3.4 is hosting the demonstration of the innovative cockpit functions in the state of the art LPA cockpit, so called Enhanced Cockpit. This work package includes also the customization needed for most of the functions, technology blocks prior to their integration,
- WP3.5 is hosting the demonstration of the Disruptive Cockpit coupled with an Integrated Modular Avionics (IMA) virtual platform. WP3.5 includes the customization and integration of innovative functions and building blocks developed with key suppliers, the integration of innovative airframer core functions and technologies, and the built-up of an IMA virtual platform. The final verification and validation of the Disruptive Cockpit will include cockpit evaluation by EASA pilots and specific pre-certification activities in close collaboration with EASA,
- WP3.6 encompasses key maintenance activities.

![Figure 6.41 – Platform 3 Work Breakdown Structure (WBS)](image)

The main interactions between the five “cockpit/avionic” related work packages are described in the following figure. The innovative avionic technologies and functions are developed in WP3.1, WP3.2, ITD Systems and other frameworks with flight validation on a case by case basis in WP3.3. They are then customized prior to their integration into the future cockpits (Enhanced Cockpit in WP3.4 and Disruptive Cockpit in WP3.5). Ground demonstrations of the Enhanced and Disruptive Cockpits are hosted in WP3.4 and WP3.5, respectively.
During Phase 1 and Phase 2-b, the airframers role will be to provide high level specifications for cockpit functions and avionic technologies. The development of these functions and technologies to be performed by the Systems suppliers represents therefore the major workload during these phases. During the integration and demonstration phases of the LPA platform 3 (i.e. Phase 2-a, Phase 3 and Phase 4), the work sharing between Systems suppliers and airframers will be inverted due to the specific integrator role of airframers.
Functions developed in WP3.1 are addressing both the Enhanced and the Disruptive cockpits. Due to the difference in the ambition and therefore in the technical objectives, the TRL 4 maturity will be reached in a different timeframe: 2018 and 2020 for Enhanced and Disruptive Cockpits, respectively. The objective of WP3.3 is to validate the subset of functions that require flight conditions by the end of 2020 for integration into the Enhanced Cockpit demonstrator and by 2022 for integration into the Disruptive Cockpit demonstrator. A TRL 5 maturity level is scheduled in 2020 for the Enhanced Cockpit and in 2022 for the Disruptive Cockpit.

N.B. The planning and TRL roadmap of the maintenance activities of WP3.6 are detailed in chapter 6.7.8.
6.7.2.4 IADP LPA Platform 3 added values versus state of the art and benefits

6.7.2.4.1 IADP LPA Platform 3 added values versus state of the art

State of the art of the large passenger aircraft, business jet and regional aircraft cockpits is summarized in the table below. Examples of state of the art non-aerospace technologies are also quoted to show possible opportunities thanks to consumers’ market trend. However, they would require major adaptation/transposition to aerospace requirements prior to integration in future cockpits (safety, certification, maintainability, life cycle ...).

<table>
<thead>
<tr>
<th>Functions</th>
<th>State of the art A350</th>
<th>State of the art Business Jet</th>
<th>State of the art Regional Aircraft</th>
<th>Examples of non-aerospace technologies (would require major transposition)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLY</td>
<td>Fly-by-wire and auto-flight with fly envelope protections</td>
<td>Fly-by-wire and auto-flight with fly envelope protections</td>
<td>Autopilot and partially fly-by-wire (auto-trim and rudder travel control)</td>
<td>Autonomous cars</td>
</tr>
<tr>
<td>NAVIGATE</td>
<td>Trajectory Optimization: Functions for fuel &amp; noise reduction; Brake to Vacate</td>
<td>Trajectory Optimization Approaches on different sensors (LPV, RNP, steep approaches, ...)</td>
<td>Trajectory optimization by FMS and GPS</td>
<td>Autonomous cars</td>
</tr>
<tr>
<td>COMMUNICATE</td>
<td>FANS B</td>
<td>CPDLC</td>
<td>VHF8.33 KHz channeling Acars thru Inmarsat</td>
<td>Voice Control</td>
</tr>
<tr>
<td>MANAGE SYSTEMS</td>
<td>Prescribed procedures; dispatch advisor</td>
<td>Dispatch advisor</td>
<td>Manufacturing Minimum equipment list (MMEL)</td>
<td>“Watson” (IBM)</td>
</tr>
<tr>
<td>MONITOR ENVIRONMENT</td>
<td>Integrated weather and traffic monitoring</td>
<td>Integrated weather and traffic Monitoring, Ground Proximity Warning</td>
<td>Weather radar, TCAS 7.1, enhanced ground proximity warning Sys. (EGPWS)</td>
<td></td>
</tr>
<tr>
<td>MONITOR CREW</td>
<td>PF/PM task sharing</td>
<td>PF/PM task sharing</td>
<td>Pilot Flying / Pilot Monitoring</td>
<td>Automotive industry, Medicine</td>
</tr>
<tr>
<td>Concept</td>
<td>OPERATIONAL CONCEPT</td>
<td>Pilot Flying / Pilot Monitoring</td>
<td>Pilot Flying / Pilot Monitoring</td>
<td>N/A</td>
</tr>
<tr>
<td>Technologies</td>
<td>FLY controls</td>
<td>Side-stick, pedals, throttles ...</td>
<td>Side-stick, pedals, throttles ...</td>
<td>Steering wheels, pedals, throttles</td>
</tr>
<tr>
<td>NAVIGATION sensors</td>
<td>High integrity architecture</td>
<td>High integrity architecture (redundancy and hybridisation)</td>
<td>High integrity architecture (cabinet)</td>
<td>MEMS</td>
</tr>
<tr>
<td>MISSION MANAGEMENT</td>
<td>Mission management - FMS: mono-bloc architecture</td>
<td>Mission management provided by FMS</td>
<td>Dual FMS</td>
<td>N/A</td>
</tr>
<tr>
<td>INTERACTIVITY on DISPLAYS</td>
<td>Point and click</td>
<td>WIMP</td>
<td>EFIS control panel</td>
<td>Tactile interaction, video games</td>
</tr>
<tr>
<td>AUGMENTED EXTERNAL VISION</td>
<td>Head-Up Display</td>
<td>Head-Up Display</td>
<td>Head-Up Display</td>
<td>Google glasses</td>
</tr>
<tr>
<td>AVIONICS</td>
<td>Integrated Modular Avionics Data Communication Networks</td>
<td>Integrated Modular Avionics</td>
<td>Integrated Modular Avionics</td>
<td>Consumer electronics</td>
</tr>
<tr>
<td>M&amp;T</td>
<td>Multiple development paradigms in the cockpit</td>
<td>Document based system engineering with external partners</td>
<td>Document based system engineering with external partners</td>
<td>Software Engineering</td>
</tr>
</tbody>
</table>

Figure 6.44 —State of the art LPA, business jet and RA cockpits. Examples of non-aerospace technologies are also shown, though they would require major transposition to aerospace requirements
The disruptive cockpit added values are expected to serve:

- **the operators with:**
  - seamless operations (less disruptions) and easier training of crews (crew population evolutions), as enablers for sustainable growth of the air transport,
  - improved performances associated to the new needs (including reduction of fuel consumption and noise) by enabling smoother and more optimized operations in flight and on ground. Weight & Recurring Costs (RC) & communication cost savings.

  Both of the above listed added values will translate into lower direct operating cost.

- **the industry and in particular the airframer by:**
  - leveraging technology to operations,
  - setting the standards to keep competitive advantage and time to market,
  - keeping the differentiation at aircraft level,
  - Reduce Cockpit & Avionics Volume allowing new aircraft capacity.

- **the community by:**
  - improving safety margins thanks to greater support given to the crew while flying in difficult conditions,
  - improving safety in approach phases,
  - improving the service for the passengers like better regularity, smoother services.

6.7.2.4.2 IADP LPA Platform 3 environmental benefits

The reduction of the air transport environmental footprint is a major objective of the Clean Sky 2 programme and is well in line with ACARE ambitious targets for the next 20 years. Benefits can be distributed over three areas:

- **Fuel saving and subsequent reduction of pollutants emission and greenhouse effect**
  Real time trajectory optimisation in all flight phases, delays reduction and resilience to adverse conditions will significantly reduce fuel consumption. In good agreement with SESAR, the FLY and NAVIGATE functions that will be developed within LPA platform 3 will take part in the fuel saving objective. Weight reduction of the cockpit and avionics platform will also contribute to fuel saving.

- **Noise reduction**
  Optimization of approach trajectories will reduce significantly noise perceived on ground.
6.7.2.5 IADP LPA Platform 3 link with other frameworks and ITD Systems

Most recent approaches and results from European and National funded R&T programs listed in the figure below will be considered as inputs to the overall LPA Platform 3.

The IADP LPA platform 3 will re-use the functions and technology bricks developed in funded programmes and in the ITD Systems WP1 as inputs to meet the LPA goals. In particular, outputs are expected from the ITD Systems platform by the end of 2017 (end of Phase 1) and in 2020 (end of Phase 2-b), as shown in the figure below.
### 6.7.2.5.1 Enhanced Cockpit interfaces with other frameworks

The candidate technologies to be possibly integrated in the enhanced cockpits are listed in the following table. They will be either transferred from other funded programmes or developed within the Clean Sky 2 framework. These corresponding frameworks are listed in the table below.

<table>
<thead>
<tr>
<th>Aerospace technologies candidate for integration (Enhanced Cockpit)</th>
<th>Funded programmes</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLY Enhanced auto-pilot robustness</td>
<td>SEFA CS2</td>
</tr>
<tr>
<td>NAVIGATE Air Traffic optimisation (4D nav.) – SESAR implementation</td>
<td>SESAR CS1 - SGO</td>
</tr>
<tr>
<td>COMMUNICATE FANS C</td>
<td>SESAR CS2</td>
</tr>
<tr>
<td>MANAGE SYSTEMS N/A</td>
<td></td>
</tr>
<tr>
<td>MONITOR ENVIRONMENT collision avoidance on ground</td>
<td>SART CS2</td>
</tr>
<tr>
<td>MONITOR CREW Fatigue management Perseveration detection</td>
<td>ACROSS SEFA CS2</td>
</tr>
<tr>
<td>OPERATIONAL CONCEPT N/A</td>
<td></td>
</tr>
<tr>
<td>FLY controls N/A</td>
<td></td>
</tr>
<tr>
<td>NAVIGATION sensors Weight and cost reduction</td>
<td>SEFA CS2</td>
</tr>
<tr>
<td>MISSION MANAGEMENT Open FMS (third party functions)</td>
<td>SEFA</td>
</tr>
<tr>
<td>INTERACTIVITY on DISPLAYS Touch-screens on limited applications</td>
<td>SEFA CS2</td>
</tr>
<tr>
<td>AUGMENTED EXTERNAL VISION Head Worn Display</td>
<td>SEFA CS2</td>
</tr>
<tr>
<td>AVIONICS Weight and cost reduction</td>
<td>PDT-AME CS2</td>
</tr>
<tr>
<td>M&amp;T Greater use of Models</td>
<td>SEFA</td>
</tr>
</tbody>
</table>

*Figure 6.47 – Enhanced cockpit technologies in various frameworks*
6.7.2.5.2 Disruptive Cockpit interfaces with other frameworks

Novel individual functions (fly, navigate, communicate, manage systems, monitor) and their supporting technologies are developed within nationally funded projects FENICS & FUMECK (all 5 functions) and a European project ACROSS (communicate, manage systems, monitor). They will be later-on integrated in the nationally funded project SEFA. The objective is to reach a TRL 4 maturity for the whole concept within this framework. In parallel, generic functions and avionics solutions, not specific to a type of aircraft or an application, will be developed in the Clean Sky 2 ITD Systems WP1.

The functions and technology bricks transferred to the IADP LPA platform 3 will be adapted to the LPA application before being integrated in the LPA Disruptive Cockpit ground demonstrator. The LPA disruptive cockpit concepts worked-out in other frameworks will be therefore disseminated to the European aerospace community.

![Figure 6.48 – Cockpit of the future (FENICS)](image)

![Figure 6.49 – Disruptive cockpit interfaces with other frameworks](image)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Funding</td>
<td>National funding (FENICS, SEFA, AME, ...)</td>
<td>‘EU funding (SESAR, ...)</td>
<td>CS2 – ITD Systems</td>
<td>CS2 – IADP LPA Plf. 3</td>
<td>EU funding (SESAR, ...)</td>
<td>CS2 – IADP LPA Plf. 3</td>
<td>National Funding (SEFA, ...)</td>
<td>CS2 – IADP LPA Plf. 3</td>
<td>National Funding (SEFA, ...)</td>
<td>CS2 – IADP LPA Plf. 3</td>
</tr>
</tbody>
</table>

Technologies / functions development

- Airbus/Dassault/Thales and other partners
- Airbus/Dassault/Thales and other partners
- Airbus/Dassault/CASA/other partners

Specific Flight tests

- Airbus/Dassault/CASA/Thales and other partners

Disruptive cockpit ground demonstrator all simulated

- Airbus

Disruptive cockpit ground demonstrator with hardware in the loop

- Airbus

Disruptive cockpit TRL

- TRL 3
- TRL 4
- TRL 5
6.7.3 “Enhanced Flight Operations and Functions” – WP3.1

a) Relevance of the Technology for H2020
In order to enable a sustainable growth of the commercial traffic, the efficiency of flight operations for the next generation of commercial aircraft is paramount. Whereas other programs, notably SESAR, are aiming at delivering improvement that could be implemented on the whole fleet (including existing aircraft), Clean Sky 2 LPA platform 3 is targeting further enhancements of the flight operations that would be firstly necessary to keep increasing the fleet while maintaining highest level of safety and efficiency and secondly that could benefit from a brand new design of the aircraft and of its systems; radical changes in operations (typically alleviating strongly the crew’s workload or allowing much more flexible type of operations in adverse conditions) are targeted and will drive requirements for new or modified functions. This will be made possible thanks to new on board equipment and cockpit design.

Competitiveness of the European industry will be enforced on one hand by setting the final product – aircraft – ahead and even a step ahead of the competition and, on another hand, by pulling all the European equipment suppliers up to this challenge thus being in a better position against their competitors.

b) Demonstration Objectives
The key objective of WP3.1 is to disseminate and implement the concepts that would be prepared in other programmes (notably French funded programs, and ITD systems) across the European avionics community and define the novel functions, not available in other frameworks, with the relevant partners, up to a functional demonstration (pilot in the loop simulation when relevant), in order to validate the functional requirements. Therefore its primary goal is to bridge the gap between “principles” defined outside Clean Sky 2 IADP LPA platform 3 and the demonstrations embedded in WP3.4 and WP3.5.

- **Functions for “always easier flight”**
  The objectives are related to the additional detection capabilities which provide:
  - better and more reliable situational awareness during all phases of operations,
  - enhanced weather awareness, turbulence, windshear, lightning, hail, ice crystals, volcanic ash and clear air turbulence detection,
  - enhanced synthetic vision on landing, collision avoidance during final approach with other aircraft / vehicles on the runway, taxi imaging in poor weather after CAT 3 landing, forward looking runway alignment verification in poor visual conditions, etc…

  The purpose of this sub-work package is therefore to provide additional capabilities to further decrease sensitivity of operations to external environment while maintaining high levels of safety. Such capability provides to the pilot better and more reliable situational awareness during all phases of operations, especially during approach and on the ground.

  - **Guidance approaches & landing systems**
  Being able to land anywhere (whatever the airport landing-aid equipment) at any time (in particular in all weather conditions) is a key driver of the efficiency of the aviation system and a good help for pilots, potentially leading to reduce their training requirements. The intent in Clean Sky 2 is to increase the maturity of solutions initiated in other research frameworks.
Three main developments are planned in this work package:

- **Guidance modes for Continuous Descent Approach (CDA)**
  Advanced CDA designs an approach phase of flight in the way that noise is reduced on lower altitudes. The control mechanism aims at enabling an access to noise-sensitive airports in high density urban areas. Fuel optimization is a secondary objective.

  The activity will consist in demonstrating an operational and technical feasibility of a new control mode to optimize Descent for business jets:
  - Operational feasibility study (ATC and Crew perspective),
  - FMS and Flight Control high level requirements on implementation of new control mode providing optimized Descent on fuel and noise,
  - Validation on simulator.

- **Approach Stabilization Assistant (AStA)**
  Assistance to Aircraft Approach Stabilization improves pilot performance during the approach so that number of un-stabilized approaches is reduced and fuel consumption is expected to be reduced.

  The activities will consist in the development and demonstration of an application prototype of decision tool to optimize timing of configuration changes to reduce number of unstable approaches and reduce the fuel consumption during last approach phase for business jets:
  - cockpit concept,
  - define algorithms by use of aircraft performance data,
  - define Human Man Interface (HMI) with respect to human-factors best practices and optimum user experience,
  - simulation shall prove decreased use of fuel in normal approaches with no effect on pilot’s performance,
  - laboratory and/or (TBC) Flight Tests with a reasonable number of pilots shall reveal improved energy management in complicated approaches with AStA on-board.

- **Landing robustness**
  The activities will consist in auto-pilot building-in robustness, robustness to weather (cross-wind) landing strip (slope) and airport equipment (landing aids) for LPA application.

  - **Collision avoidance**
    - In flight: the study will investigate the operational and technical feasibility on bizjets of Interval Management, and Advanced visual separation,
    - On ground: airport taxiway, apron and ramp are more and more crowded. Hence, in poor weather condition the risk of collision at low speed with another airplane or a ground vehicle is real. Means to support the crew navigating this area is thus needed.

  Primary goal is to investigate potential enhancement of the currently installed sensors and assess the opportunities to introduce new sensors for the obstacle and debris detection. The assessment of the performance and business justification (use cases) will be key factors for selection and design of the system. The preference is given to the radar technology enhancements however other sensors will be also taken into account.

  In the following phase design of the interfaces to the sensors and display unit, pre-processing of the information to defined form and design of the fusion module is planned. The fusion module will process
information from the sensors, from databases and from real-time surface awareness system. This fusion allows providing complex information on the surrounding situation and will improve safety and situational awareness.

The platform will integrate following innovative technologies:
- On-board obstacle, object and debris detection sensors,
- Terrain and obstacles databases enabling both external landscape rendering as well as advanced functions,
- Real-time surface data fusion via reliable data link,
- 3D rendering capability with possibility to overlay different types of symbology.

Surveillance equipments will be integrated on ground cockpit demonstrator for operational concepts assessment.

- **Head-out vision systems**
  
The main objective of this activity is to enhance crew operation by using visual projection technologies. Head-out vision systems activities will be two-fold: define System requirements for novel head-out vision systems, and explore new cockpit applications enabling higher situational awareness and operational benefits.

  - **Head-Worn Display**
    
    Current Head-Up Display technology is highly performing to help the crew operate the aircraft. However, its cost is prohibitive. Head-worn Display (lenses integrating some image projection capability) is a promising technology, addressing the HUD cost issue and offering opportunities for new functions ("see through skin" for example). This technology is candidate for embodiment on derivative airplanes.

  - **Enhancement Light Weight Eye Visor**
    
    This activity will consist in the development of the “Light Weight Eye Visor” technology, the integration of this technology on the operational cockpit environment to perform Human Factors assessments and the demonstration of its expected operational benefits.

    The main objectives are:
    - To reduce visual transition in/out the cockpit in critical phases of flight (T/O, LDG, Approach),
    - To increase, integrate and processing data from sensors and systems providing to the crew the needed information relevant to the tasks, especially at the critical flight phases,
    - New SMART Head-up symbology development, visible and readable in all external light lighting conditions, in order to improve flight crew situation awareness and minimize cluttering.

- **New navigation sensor and Hybridization**
  
  Enhancement in navigation is required to support gate to gate navigation which will have a huge impact on future cockpits and pilot tasks. Improvement axes are twofold:

  - In flight: increase integrity of attitude, speed and possibly position data while decreasing overall cost of the navigation platform. Special attention shall be given to the robustness of the architecture during the approach and landing phase,
  - On ground: increase of speed and position accuracy, improvement of data integrity while limiting cost impacts.
Within the LPA platform 3, two main areas will be addressed for LPA and business jet:

- **Dual Frequency Multi Constellation GNSS (DFMC)**
  
  The aim is to demonstrate improved attitude, velocity and position in all flight phases worldwide enabled by the use of several GNSS constellations for the aircraft navigation system.

  The activities are to support development effort to mature DFMC GNSS receiver:
  - identify the operational requirements,
  - identify navigation performance needed to meet requirements, preliminary safety analysis and fault tree analysis,
  - data collection campaign to assess performance of new signals and impact of multipath and interference,
  - prototype the required sensor, from adaptation of existing elements,
  - flight tests to demonstrate the identified operational benefits.

- **Hybridized Navigation systems**

  The aim is to achieve:
  - better integrity and continuity of position and velocity data during approach and landing,
  - alternative navigation aids for better accuracy.

  The proposed hybridized navigation systems activities are:
  - performance studies of navigation systems replacement by DFMC GNSS with additional A/C sensors (including MEMS inertial sensors),
  - assessment of airworthiness and certification aspects,
  - development and integration of GPS/INS based on MEMS inertial sensors prototype,
  - flight test campaign using prototypes to assess performance of GPS/INS and to collect data for GNSS/INS.

Overall LPA strategy for the selection of GNSS constellations to be used will be defined as part of SESAR. This includes number of constellations to be available in large aircraft, number of constellations used simultaneously at one point in time, method of selection of constellations in use. Maturation of GNSS receiver technology will be continued under SESAR extension. LPA platform 3 activities will focus on hybridization of the different navigation means.

- **Functions for efficient and easy systems management**

  The goal is to simplify the flight crew interactions in the cockpit and reduce pilot workload keeping flight safety level and mission effectiveness. In this context, several technologies are proposed.

  - **Automatic Fuel leakage detection and Control**

    The use of online fuel leaks detection will allow fuel system to prevent, identify and isolate any foreseeable source of fuel leaks due to loss of integrity of the fuel system during the flight in real-time, improving the operational and maintenance aspects.

    Fuel leaks detection and control technologies and algorithms should be studied to be implemented in aircraft environment, considering important aspects as weight and cost minimization.

    This project involves the study of different technologies and techniques for fuel leaks detection, development and simulation of fuel leaks detections algorithms, and finally to provide the capability of reconfiguring automatically the system in case of unacceptable leak detection. The main working paths are as follows:
- **System Failure Cockpit**
  The activity will consist in the development of the “System Failure Cockpit Automation” technology, the integration of this technology on the operational regional cockpit environment and the demonstration of how this technology contributes to the stated objectives.
  The main objectives of this activity are:
  o to define a new approach in the crew action philosophy either during normal operation or after system failure occurrence in order to increase procedure automation during the checklist running,
  o to increase crew mental spare capacity, especially during emergency situations,
  o to re-orientate crew task from system management to other tasks that would request more demand.

- **Functions and solutions for man-machine efficiency**
  **- Pilot Monitoring System**
  During operations in a complex environment, critical phases of flight or degraded conditions requiring a large concentration, the pilot health monitoring is crucial as the effectiveness of the pilot could be reduced because of the fatigue and stress. Advanced technologies are thus developed to record stress level and overall pilot health status by means of monitoring pilot physiological and biomedical parameters. This monitoring data will be used to state on the pilot mental and physical conditions which could be extracted using signal filtering and data processing. This level would be compared with a predicted pattern in order to determinate the level of pilot response and potential performance degradation. The monitoring system will provide the information to aircraft control systems to reduce the pilot workload.
  Within the LPA platform 3, the studied pilot monitoring technologies objectives are:
  o to identify the relevant physiologic parameter for stress and fatigue pilot measurement,
  o to define pattern for pilot behavioural during complex environment, critical phase of flight or degraded conditions,
  o to develop new non-intrusive suit of parametric sensors (Blood Volume Pressure (BPD), Galvanic Skin Response (GSR), Skin Temperature (ST), Breath (RR), Heart Rate Variability (HRV), Eye movement (Eye Tracker),...),
  o to have new data acquisition and processing pilot monitoring system,
  o to develop new concept for prognostic and diagnostic techniques applied to pilot monitoring.

- **Voice to System & Multimodality**
  o *System able to understand voice from ATC/AOC*
  Understanding what Air Traffic Controller is communicating to the crew can be sometimes difficult because of noisy transmission, controllers & crew English skills or pronounced regional accents... Having the message in written would be therefore helpful. Voice recognition software is today standards in many consumer products such as smartphones. Although they are not currently fitted to aviation application, this domain is worth exploring.
Voce Command
The activity will consist in the development of the “Voice to system” technology, the integration of this technology on the operational cockpit environment and the demonstration of how this technology helps to contribute to the stated objectives. The main objective is to propose new cockpit control means techniques by using speech recognition technology as a solution to be applied and used within the cockpit environment by the flight crew, as help to perform their duties during the flight. In particular, the goals are:

- to reduce crew manual interaction in the cockpit,
- to reduce the number of dedicated mechanical controls,
- to increase manual crew spare activity capacity.

An effort must be done on voice commands human factors development, were the following aspects needs to be considered:

- speech recognition rate in all phases of flight and different cockpit noise condition,
- voice command structure definition for improving crew usability. The crew will feel this control means as a natural way of controlling the cockpit systems.

Finally, a voice command recognition feedback using visual means for the crew need to be developed either for voice commands from the crew or from the Air Traffic Control. The “Enhancement Light Weight Eye Visor” will be used for such purpose.

Multimodal integration
Today interactions modalities in the cockpit are the classical displays and controls (cursor control device and physical buttons). Humans use more than visual and touch modalities for an efficient dialog with each other. For the future, in order to develop a more intuitive and natural cockpit (man-machine efficiency) other modalities like voice are promising to integrate.

Even if each new modality (especially voice) has to be defined and assessed (in term of intended function and performance), the integration has to be done in a global view of interaction:

- Primary means versus secondary (to ensure quality of service),
- Crossed modality to enhance performance (example: voice + gaze),
- New intended functions (example: speech to text from ATC for better understanding).

The activities foreseen in this work-package will be common to LPA and bizjet cockpits:

- Definition of cross modality utilization concept,
- Prototyping of individual technologies for interaction,
- Integration of individual technologies for interaction
- Evaluation of individual technologies for interaction,
- Evaluation of integrated multi modal technologies.

Tactile HMI
Touchscreens are an easy and intuitive way to interact with a system and may prove cheaper than knobs, buttons etc... Moreover, new pilots are naturally proficient with this technology. A good example is the swipe of charts directly with fingers (better affordance than using a third party between screen and user – mouse or CCD). This is well popularized with the tablets and touch OS coming from the mass-market (iOS, Android, ...). The touch modality could be used as an intuitive interaction in the cockpit.
However, current technology level of the avionics industry is likely to be adequate for low to medium
critica1ity. A step in safety and robustness of this kind of interface is needed to allow its generalization to
all cockpit functions.

Three main axes will be studied jointly with LPA and business jets airframers:

- Explore and utilize the potential of new available technologies (e.g. Touchscreen, Speech, …) and
  its integration in commercial cockpit (LPA, Business Jets) taking into account aircraft environment
- Define and develop framework, tooling and human factors evaluation process (taking into
  account the physical ergonomics), H/W and S/W qualification
- Define a standard certification approach for selected innovative HMI technologies

A concept applicable to bizjets will be defined initially using existing technologies, and integrated in a
bizjet cockpit concept. Based on evaluations from simulations and potentially from flight test of
 technological elements, the technologies will be adapted to support a viable tactile MMI concept.
In parallel, tactile HMI will be a component of the LPA disruptive concept.

c) Added-value versus state-of-the-art

The key added value is to focus the crew’s role on the value-added tasks that request manned decision-making and
control, whereas alleviating the difficulty of the tasks, especially in adverse conditions (weather, failure cases, etc.).
Ultimately “always easier” flight operations will allow for different skill requirements for the crew, for example less
to do to handle flight dynamics aircraft behaviour, or ability to continue operating in adverse situations without
major disruption – and keeping the necessary level of flight safety. Additionally, significant redesign of some
functional requirements would enable to think differently about physical concept and implementation of the
functions on board, offering significant opportunities for weight saving or better space usage in the fuselage to
perform the required functions.

The generic objective “industrial leadership” (airframer and systems/ function suppliers) and “mobility” are relevant
for this WP and more generally for Platform 3.

As end users, Airbus, Dassault and CASA will cooperate with key European partners on integrating on board the new
systems. Some of them will be tested at systems level in the ITD systems.

d) High-level WBS and work-sharing

The work breakdown structure of WP3.1 is straight aligned to define the set of functions to facilitate intuitive
operation of aircrafts in the next generation cockpit. The major difference to conventional concepts is to replace the
operation of typically a number of individual systems or system components by smart functions. These functions can
be grouped to those related to operate respectively “fly” the aircraft, to those related to mission and trajectory
management, and to those to operate complex aircraft systems.

WP3.1 is providing most of the specifications and setting of requirements for Platform 3 Work Programme.
Details of the activities and stakeholders within WP3.1 are summarized in table 6.53.
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<th>Enhanced Flight Operations and Functions</th>
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<td>Guidance approaches &amp; landing systems</td>
</tr>
<tr>
<td>WP 3.1.1.2</td>
<td>Collision avoidance</td>
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<td>WP 3.1.1.2.1</td>
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<td>WP 3.1.1.2.2</td>
<td>Collision avoidance in flight</td>
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<td>WP 3.1.1.3</td>
<td>Head Worn Display</td>
</tr>
<tr>
<td>WP 3.1.1.3.1</td>
<td>Head Worn Display</td>
</tr>
<tr>
<td>WP 3.1.1.3.2</td>
<td>Enhancement Light Weight Eye Visor</td>
</tr>
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<td>WP 3.1.1.4</td>
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</tr>
<tr>
<td>WP 3.1.2</td>
<td>Functions for efficient and easy systems management</td>
</tr>
<tr>
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<td>WP 3.1.2.2</td>
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<td>WP 3.1.3.2</td>
<td>Voice to System &amp; Multimodality</td>
</tr>
<tr>
<td>WP 3.1.3.2.1</td>
<td>System able to understand voice from ATC/AOC</td>
</tr>
<tr>
<td>WP 3.1.3.2.2</td>
<td>Voice command</td>
</tr>
<tr>
<td>WP 3.1.3.2.3</td>
<td>Multimodal integration</td>
</tr>
<tr>
<td>WP 3.1.3.3</td>
<td>Tactile HMI</td>
</tr>
</tbody>
</table>

**Figure 6.52 – Platform 3 WP3.1 activities and proposed work package leaders**
e) Interactions with Clean Sky 2 ITDs, IADPs, other interfaces
WP3.1 will primarily take results and orientations from French funded projects (FENICS/FUMSECK/SEFA) and EU-funded (ACROSS, Clean Sky 2 ITD Systems) as inputs and feed requirements to all other IADP Platform 3 level 1 work packages.

SEFA, for instance, will develop activities around cockpit, FMS and advanced functions. It will prepare new technology solutions, new configurations, and new functions and make them safer with an increase of competitiveness. It is also proposed to develop frameworks to provide airframers with capability to customize IHS and FM without provider involvement. This is especially helpful when the airframers want to differentiate their product.

In addition, there is a mainline exchange planned with the Technology Evaluator work package as described in the related chapter.

f) Budget provisions
The total effort for the full scope of activities, including principle Clean Sky members, Core-Partners, CfP-Partners and activities through Call for Tender will be 34 M€ gross (i.e. 17 M€ in EU funding).

g) Synthesis of added-value with respect to H2020 targets
Refer to chapter 6.7.9.
6.7.4 “Innovative enabling technologies” – WP3.2

a) Relevance of the Technology for H2020
In order to prepare the integrated demonstration (refer to chapter 6.6.6 and 6.6.7), the aim of WP3.2 is to bridge the gap between functional requirements (notably those coming from WP3.1, but also from other funding frameworks) and enabling resource. Thus, it will complement the results of WP3.1 to demonstrate the feasibility of key specific technologies not developed in other frameworks.

b) Demonstration Objectives
Based on the results of other R&T programs, including Clean Sky 2 ITD systems WP1, the objectives of WP3.2 is to develop the additional avionics technologies necessary to implement and integrate the novel functions developed in WP3.1, and aircraft utilities on flexible communication, command & control, avionics components.

- **Flexible communication**
  The purpose of this module is to demonstrate the feasibility to put together a communication platform matching future cockpit needs in terms of air/ground radio link availability, security, data rate and data integrity. Higher integration is foreseen between ground and flight with increased need for data exchange, voice communications and possibly video communications. The platform will integrate the following innovative technologies:
  - **ATN/IPS router**: ATN/IPS router to use best available communication link at any time while taking advantage of latest routing techniques for maximum data rate.
  - **Modular Radio Avionics**: Software Defined Radio (SDR) communication unit demonstrating the capability to manage several radio frequency links within a single unit for maximum flexibility and lower cost and weight. Part of the activity should be also the development of integrated multi-band antennas taking the advantage of SDR capabilities to optimize function allocation between antennas and communication units, especially to remove coaxial cables and combine multiple systems into one solution.

  The communication link performance (smart antenna and SDR communication unit) will be assessed using real equipments on ground or in flight as appropriate. As a result of these tests link availability statistics and associated scenarios will be provided to the cockpit demonstrator. The ATN/IPS router will be integrated in the ground disruptive cockpit demonstrator in order to assess a number of communication link reconfiguration scenarios.

  This work package will address both bizjets and LPA applications. Analysis of the impact of the architectures on bizjets and LPA will be performed.

- **Aircraft Monitoring Chain for Ground Support**
  This project intends to analyse the potential benefits and propose a corresponding technical solution to provide support to pilot(s) operation under specific situations (e.g. degraded systems, high workload, and emergency situations) via remote on-ground support technologies.

  In particular, the objectives of this project are:
  - to allow the Ground support operator to provide the proper assistance to the on-board pilot(s) in order to ensure a safe operation and to maintain the aircraft(s) integrated into the Air Traffic Management infrastructures,
  - to provide the remote operator with an adequate HMI to this operational environment where several aircrafts are monitored simultaneously,
- to analyse the workload and tasks required to this remote operator will be also provided, in basis of the prototype of the ground control station to be developed,
- to analyse the needs and necessary means in terms of communication system(s) to ensure the capabilities above mentioned.

This project is consistent with the other technologies focused on pilot workload reductions.

- **Avionic components update**
  The objective is to adapt and configure some equipment’s and framework delivered by PDT AME (French National), ASHLEY (EU project) and ITD System equipment’s to the needs of the WP3.5 demonstration.

  As an example, the Remote Data and Power Cabinet (RDPC) architecture developed in other frameworks such as PDT-AME will be simplified and its compliance for both LPA and bizjets will be demonstrated. This activity will be divided into two phases: short/medium term phase dedicated to bizjets and medium/long term phase dedicated to LPA.

c) **Added-value versus state-of-the-art**
   The key added value is to define and develop technology enablers for implementation of advanced functions.

d) **High-level WBS and work-sharing**
   The WP3.2 structure is detailed in the figure below.

   ![Figure 6.54 – WP3.2 Principle Work Breakdown Structure (WBS)](image)

   Details of the activities and stakeholders within WP3.2 are summarized in the table below:
e) Interactions with Clean Sky 2 ITDs, IADPs, other interfaces
WP3.2 will take inputs, results and orientations from various funded projects. Inputs will also be taken from the output of work packages WP1 in the ITD Systems.

In addition, there is a mainline exchange planned with the Technology Evaluator (TE) work packages as described in the related chapter.

f) Budget provisions
The total effort for the full scope of activities, including principle Clean Sky members, Core Partners (CPs), Partners (CfPs) and activities through Call for Tender will be 26 M€ gross (i.e. 13 M€ in EU funding).

g) Synthesis of added value with respect to H2020 targets
Refer to chapter 6.7.9.
6.7.5 “Next generation cockpit functions flight demonstration” – WP3.3

a) Relevance of the Technology for H2020

WP3.1 (with support from WP3.2) is preparing functions that will enhance the flight operations to the level necessary to keep increasing the fleet while maintaining highest level of safety and efficiency thus enabling a sustainable growth of the commercial traffic. For most of these functions, flight tests (of WP3.3) are needed to demonstrate the right level of validation.

b) Demonstration Objectives

The key objective is to test in flight the subset of functions where flight environment is of paramount importance (e.g. approach and landing) to:

- put the crew in realistic conditions including external visual clues (see and avoid),
- monitor the dynamic behaviour of the flight test vehicle and its systems,
- monitor real time performance of control loops, etc...

This work package does not aim at comprehensive coverage of the function nor the test cases, it is targeting specific functions or flight conditions where a subset of functionalities is required. It can demonstrate “isolated” features in a case-by-case specific test environment. Note that before flight tests, a test on a ground simulator will be performed to ensure proper integration on the airplane. The flight tests planned in WP3.3 and their objectives are summarized in the table below.

<table>
<thead>
<tr>
<th>Flight test</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot Monitoring</td>
<td>Demonstration of the capability of a system to detect different levels of crew incapacitation. Fortunately crew incapacitation (high level of fatigue, perseverance ...) occurrence is a rare event. Hence, such an event can be detected only in case of long exposure. The test vehicle would be airplanes in airline operations, equipped with a crew monitoring system. Operations would be the normal airline operations. In case of detection of an incapacitation, and with the agreement of the crew, a medical investigation would be triggered to check the accuracy of the detection.</td>
</tr>
<tr>
<td>Auto-Pilot</td>
<td>Demonstration of the capability to land anywhere at any time. The test vehicle will be a flight test airplane. This means to execute automatic landings without using the full visibility provided by the cockpit glare shield and without using ground support such that the Instrument Landing System.</td>
</tr>
<tr>
<td>Approach Stabilization Assistant</td>
<td>Demonstration of the function on a test airplane.</td>
</tr>
<tr>
<td>Collision avoidance in flight</td>
<td>Evaluation in flight of the function (while keeping the insertion in air traffic system).</td>
</tr>
<tr>
<td>Ground collision avoidance</td>
<td>Demonstration of the capability of the system to detect moving vehicles and fixed building. The test vehicle will be a test aircraft, moving around an airport in low visibility conditions.</td>
</tr>
<tr>
<td>Head Worn Display</td>
<td>Demonstration of the capability to perform approaches and landing with the sole means of this system. The test vehicle will be a test aircraft.</td>
</tr>
<tr>
<td>Ground/board communication</td>
<td>Demonstration of communication link performance (smart antenna and SDR communication unit). The test vehicle will be a test aircraft.</td>
</tr>
<tr>
<td>New navigation sensors and hybridization</td>
<td>Validation of the accuracy, availability and integrity of navigation parameters either directly measured or merged (hybridization) from different sources (IRS/AHRS/GNSS). The test vehicle will be a flight test airplane.</td>
</tr>
<tr>
<td>Voice to System</td>
<td>Demonstration of the versatility of the system and of its robustness to different accent and mother tongue of air traffic controllers. The test vehicle would be airplanes in airline operations to get large and realistic exposure with an instrumentation recording the message spoken by the controller and the text as translated by the system.</td>
</tr>
</tbody>
</table>

Figure 6.56 – Flight tests plan
c) Added value versus state-of-the-art
Added value of WP3.3 is to contribute to validate and tune the functions and avionics technologies defined in WP3.1 and WP3.2, respectively, hence contributing to hit the same target.

d) High-level WBS and work-sharing

Figure 6.57 – WP3.3 Principle Work Breakdown Structure (WBS)

Details of the activities and stakeholders within WP3.3 are summarized in the table below.
Figure 6.58 – Platform 3 WP3.3 activities and proposed work package leaders

e) Interactions with *Clean Sky 2* ITDs, IADPs, other interfaces
As fed through work packages WP3.1 and WP3.2, essential inputs will be results and orientations from French funded projects (notably PDT AME), the German LUFO V and EU-funded (ASHLEY).

Input will also be taken from the output of work packages WP1 in the Systems ITD. In addition, there is a mainline exchange planned with the Technology Evaluator (TE) work packages as described in the related chapter.

f) Budget provisions
The total effort for the full scope of activities, including principle *Clean Sky* members, Core-Partners, CfP-Partners and activities through Call for Tender will be 36 M€ gross (i.e. 18 M€ in EU funding).

g) Synthesis of added-value with respect to H2020 targets
Refer to chapter 6.7.9.
6.7.6 “Enhanced Cockpit demonstration” – WP3.4

a) Relevance of the Technology for H2020
Maturity on technologies that are addressed in WP 3.1, WP3.2 or ITD Systems WP1, SESAR and SEFA may be sufficient for embodiment in the airplanes that will be derived from existing aircraft families. On Large Passenger Airplanes, these derivative programs are likely to be an early opportunity to cash in these technologies and to enhance accordingly the flight operations and the capacity to let the commercial traffic grow in a sustainable manner.

b) Demonstration Objectives
The objective is to check that the value added to the airplane is worth the investment and to check that the candidate technology can properly be integrated into the targeted platform.

Components or functions that are targeting embodiment on existing or derivative aircraft will be integrated in existing simulators:

- a versatile one (like Airbus MOSART) to integrate a customized version of the generic Cockpit Display System and of the Flight Management System (both from ITD Systems WP1), functions and technologies developed in WP 3.1 and 3.2 and in SEFA, functions developed in SESAR. The operational concept will be “one step beyond” A350 concept, although not a step change (for the new technologies to be reasonably candidate for early embodiment in a derivative version of an existing large passenger aircraft),
- specific ones (like an A320 simulator) to integrate technologies with a direct application on an existing large passenger aircraft. When relevant, other specific simulator (e.g. business jet) will be sued to demonstrate integration of the functions in a full cockpit environment.

The MOSART test platform (In Airbus facilities) is used to validate upstream research concepts in an operational and representative cockpit, with simulated and realistic environment (Weather, ATC, etc.). This platform will provide one starting point for the Clean Sky 2 cockpit demonstrator.

Figure 6.59 - The MOSART test platform

The objective is also to adapt and configure IMA & IMA2G avionics equipment’s and framework to the needs of the enhanced cockpit demonstration:

- Define the equipment needs and Specify Avionic Equipment adaptations: to capture the needs of all the System based on Scenario demonstration.
- Platform demonstration architecture design and validation (modelling) to define and model the Cockpit demonstrations Avionics Platforms with the mapping of the functions & others equipment’s
• Develop Avionic Equipment adaptation’s or some new one when critical for the overall demonstration in particular for data security purpose

c) **Added-value versus state-of-the-art**
Refer to WP 3.1 and WP3.2

d) **High-level WBS and work-sharing**
Checking that the integration of a technology in a given airplane is properly feasible is generally relying on test on a cockpit test bench of the targeted airplane. These tests are thus planned and specified (WP 3.4.1), then the test-bench is adapted, the new equipment or function is installed (WP 3.4.2), the IMA platform is adapted (WP3.4.3), tests are done (WP 3.4.4) and the results of the tests are analysed (WP 3.4.5).

![Figure 6.60 – WP3.4 Principle Work Breakdown Structure (WBS)](image)

Details of the activities and stakeholders within WP3.4 are summarized in the table below:

![Figure 6.61 – Platform 3 WP3.4 activities and proposed work package leaders](image)

e) **Planning roadmap, targeted technology readiness levels**
f) Interactions with Clean Sky 2 ITDs, IADPs, other interfaces
Refer to chapter 6.7.2.5

g) Budget provisions
The total effort for the full-scope of activities, including principle Clean Sky members, Core-Partners, CfP-Partners and activities through Call for Tender will be 28 M€ gross (i.e. 14 M€ in EU funding).

h) Synthesis of added value with respect to H2020 targets
Refer to chapter 6.7.9.
6.7.7 “Disruptive Cockpit demonstration” – WP3.5

a) Relevance of the Technology for H2020
The integration of the functions and technologies developed and validated in WP 3.1, WP3.2, WP3.3, ITD Systems WP1, SESAR and SEFA in a consistent operational concept will provide the European industry with a disruptive cockpit, enabling a step change ahead of the competition. This will enable a significant increase in the resilience of operations and a new crew resource management paradigm. In turn, this is a key enabler for a sustainable growth of the commercial traffic.

b) Demonstration Objectives

- Overall objectives
The disruptive cockpit ground demonstrator is the ultimate test of the disruptive cockpit concept. The final decision for its development readiness will be a crucial outcome of this work package (as a reminder, go ahead for full development beyond R&T phase would be based on such demonstration).

The key objective is to develop a highly representative cockpit simulator, embedding all the novel functionalities and allowing demonstrating the flight operations in a realistic (simulated) environment. The ground demonstrator is foreseen to be similar to existing MOSART and is likely to re-use existing components. The demonstrator will be built to:

- Simulate the complete cockpit and to be fully representative as seen by the crew,
- Integrate real and simulated components,
- Be flexible enough to support the evaluation of different configurations in term of physical and functional organization (i.e. different seats location, different fly controls, different data displayed) and to switch easily between real and simulated components.

This real time, crew-in-the-loop simulator will include all the functionalities needed to validate the proposed concepts, and – when relevant – will include real hardware from avionic platforms and embedded functions. To ensure that the simulation of a component is sufficiently representative, testing of such component on a dedicated test bench may be required. Having an overall validation plan is thus mandatory. It may prove simpler to integrate the component in the ground demonstrator. This decision will be taken based on evidences during the gate review scheduled prior to the demonstrator integration launch.

Putting the crew in a quite realistic simulator (functions, ergonomics, performances of the systems, external operational environment including adverse conditions) will allow for comprehensive validation of the novel type of operations.

In addition to airplane manufacturer experts (in cockpit design, human factors, flight test pilots, flight instructors), the new concept must be evaluated by external stake-holders:

- Aviation Safety Agency (EASA) and Air Traffic Management Agency (EUROCONTROL) to benefit from their advices and to assess the potential impact on the regulation and the means to show compliance,
- Airlines representatives to assess the impact on their operations.
• Virtual platform objectives
The Virtual Platform will allow integrating various avionics function in representative environment with typical performance of some of the IMA resources not available in the highly representative cockpit MOSART simulator. Thanks to the flexibility of the virtual platform, configuration change of the cockpit simulator will be easily done to support the various level of integration necessary for each individual demonstration with the relevant suppliers.

The ultimate objective is to create an IMA virtual platform in both simulated and real environment necessary to demonstrate the new cockpit functions. To reach this objective, common methodology and approach are to be set-up between airframer and supplier enabling various IMA2G+ platform resources integration in an open way model. To that end, the following activities will be performed:

- platform architecture (modelling),
- avionics platform emulator definition, integration and validation,
- test bench adaptation to the virtual platform,
- specification of new IMA2G+ component for disruptive cockpit demonstration,
- IMA2G+ Avionics component model development or adaptation by the suppliers,
- integration of new application on virtual platform,
- verification and tests to validate the applications on the test bench with the support of key suppliers.

c) Added-value versus state-of-the-art
Added value of WP3.5 is to contribute to validate and tune the functions defined in WP3.1 and avionics technologies defined in WP3.1 and WP3.2, respectively, hence contributing to hit the same target.

The IMA virtual platform will reduce time to market allowing the LPA airframer to adapt easily the IMA resources to ensure in a co-design approach good matching between the IMA platform and the functions. New IMA platform could be then easily created based on the different bricks proposed by the suppliers in both simulated and real environment necessary to demonstrate the new cockpit functions.

The final benefit will be in the level of coverage and the fidelity thus in the confidence in the results of the demonstration: operational and functional demonstration with high confidence in the feasibility of the technical enabler for such functions and operations.

d) High-level WBS and work-sharing
The architecture of WP3.5 is straightforward tailored to develop the demonstrator, network it to optional hardware components for “hardware-in the loop” testing, connect it the sources of simulating a realistic environment, and to test and qualify the full scope of its functionalities. Human factors and environmental evaluation will be part of the verification and validation sub-work package (WP3.5.5). WP 3.5.1 is covering the ground demonstrator and also the partial test-benches used to validate the model of simulated components.
Details of the activities and stakeholders within WP3.5 are summarized in the table below.
### WP 3.5
Disruptive Cockpit demonstration

| WP 3.5.1 | Tests & test means specification |
| WP 3.5.2 | Test means & equipment adaptation |
| WP 3.5.2.1 | Common hardware equipment adaptation |
| WP 3.5.2.2 | Customization of functions & equipment from partner A |
| WP 3.5.2.3 | Customization of functions & equipment from partner B |
| WP 3.5.2.4 | Operational environment adaptation |

| WP 3.5.3 | IMA virtual platform |
| WP 3.5.3.1 | Platform demonstration architecture design and validation (modelling) |
| WP 3.5.3.2 | Avionics platform emulator definition, integration and validation |
| WP 3.5.3.3 | Test means adaptation |
| WP 3.5.3.4 | Verification & tests |
| WP 3.5.3.4.1 | Verification of the integration of the application with Configuration on the platform |
| WP 3.5.3.4.2 | Support Airbus demo with platform suppliers |

| WP 3.5.4 | Disruptive cockpit tests |
| WP 3.5.4.1 | Disruptive Cockpit Tests - integration of innovative functions & technologies from partner A |
| WP 3.5.4.2 | Disruptive Cockpit Tests - integration of innovative functions & technologies from partner B |
| WP 3.5.4.3 | Integration of innovative core functions & technologies |

| WP 3.5.5 | Verification and validation |
| WP 3.5.5.1 | Human factors evaluation |
| WP 3.5.5.2 | Environment evaluation |
| WP 3.5.5.3 | Validation of the integration |

Figure 6.64 – Platform 3 WP.5 activities and proposed work package leaders
e) Planning roadmap, targeted technology readiness levels

![Figure 6.65 – Disruptive Cockpit TRL roadmap](image)

f) Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

This WP is the final integration of the other IADP LPA platform 3 work packages, of components or their models developed in ITD System WP1 (and possibly other Programs), from a concept developed in National Program “SEFA”. This new cockpit must be compatible of functions developed in SESAR. The sizing ones will be thus integrated too.

The validation of the Disruptive Cockpit will be performed in collaboration with EASA (WP3.5.5.3) for:

- the Disruptive Cockpit evaluation by EASA pilots to gain confidence in the validity of the concept,
• preparing the certification of the disruptive cockpit. The identification of possible impact of this new concept to the regulation as well as the determination of possible means of compliance will be studied.

g) Budget provisions
The total effort for the full-scope of activities, including principle Clean Sky members, Core-Partners, CfP-Partners and activities through Call for Tender will be 68 M€ gross (i.e. 34 M€ in EU funding).

h) Synthesis of added value with respect to H2020 targets
Refer to chapter 6.6.9.
6.7.8 “Maintenance” – WP3.6

a) Relevance of the Technology for H2020

Passengers leaving and arriving on time is the service that an economic efficient and reliable transport system needs to provide. Aircraft scheduled and unscheduled maintenance continues to disrupt operations in Europe and reduces the asset utilization. The challenge to be addressed is the development of a value driven end-to-end maintenance service architecture enabling the replacement of systematic scheduled maintenance by on-condition maintenance. The impact of service architectures on the value chain of the main actors (Airlines, MROs, OEM and suppliers) with theirs highly diversified operational environments and business constraints and thus their economic efficiency provides additional challenges.

With WP3.6 “Maintenance” the H2020 challenges on seamless air mobility, industrial leadership and competitiveness will be addressed by enhanced reliability and affordability of the air transport system through less operational disruptions and higher maintenance economics efficiency. The demonstration will be provided on the basis of a multidisciplinary integration of aircraft and ground based health monitoring and management and maintenance supporting technologies into a service oriented, operational focused, collaborative environment.

WP3.6 Maintenance provides only a first step on the way to achieve the global vision beyond 2020 of no operational disruptions in the European air traffic due to maintenance activities. This vision is complemented by an optimized aircraft and maintenance asset utilization supported by a value chain optimized E2E service architecture.

WP3.6 Maintenance will provide the technical basis for the integration of enabling technologies such as e.g. structure and system health monitoring and condition based maintenance solutions into a fleet level operational and service driven environment. It will provide the short term enhancements for the legacy fleet. But it will also provide the foundation for E2E service architecture development, optimization and integration, design rules and principles, operational and economic relevant scenarios and recommendation to all other Clean Sky 2 domains (Regional Aircraft LPA, Rotorcraft LPA, airframe, powerplant and systems ITD).

b) Demonstration Objectives

WP3.6 Maintenance provides validation for the global end-to-end maintenance service architecture in an operator fleet environment and demonstration of the technical and operational maturity of the enabling technologies integrated at higher level into the global architecture.

With respect to the relevance of the topic to H2020 challenges demonstration shall be provided for:

- Reduction of operational disruption caused by unscheduled maintenance for the European legacy fleet and short term derivatives
- Maximization of airline and maintenance asset utilization (aircrafts, maintenance resources and infrastructure)
- Improvement of the value chain through services for the main actors (Airlines, MROs, OEMs, Supplier)
- Exploration of the impact of new services on the way of working for maintenance actors
- Improvement of maintenance economics with focus on early opportunities for the legacy fleet and short term product derivatives

The multidisciplinary integration of different technologies emerging out of the Clean Sky 2, FP7 and other European or national funded research activities, require a thorough selection of state-of-art technologies and
their integration into the end-to-end maintenance service architecture. To achieve the demonstration objectives and taking into account the multidisciplinary integration constraints in WP3.6 the following specific demonstration activities are foreseen:

- Development and validation of the technical feasibility of a service oriented architecture with respect to performance and economic efficiency and its impact on the economic environment
- Demonstration of aircraft/ground integrated health monitoring functionalities considering the legacy fleet technical capabilities
- Validation and evaluation of the certification and security needs
- Demonstration of the operational maturity of structure and system health monitoring technologies for selected use cases
- Demonstration of the maturity and performance of prognostic methods and condition based maintenance principles
- Demonstration of technical maturity and efficiency of a collaborative IT infrastructure integrating multiple sources of information and providing sufficient resources for the purpose of Data Mining
- Demonstration of Data Mining and consolidation solutions to feed configuration management, maintenance planning and optimization functions
- Demonstration of the maturity and efficiency of configuration management and maintenance planning and performance optimization functions on operators fleet level
- Demonstration of technical maturity and operational efficiency of the application of augmented/virtual reality solutions and maintenance tool boxes providing capabilities for contextualized documentation, online damage assessments and reporting during maintenance execution in an airline environment
- Demonstration of maintenance performance enhancement through the development and application of maintenance control center toolkits for remote support functions including two way communication, data link to line maintenance by mobile tools and integration in the collaborative environment

For all demonstration activities it is understood, that in principle only moderate modifications of aircrafts in the legacy fleet are feasible. All demonstrations shall include commercial type operational and economic scenarios of large passenger aircraft or being carried in a real airline environment.

c) **Added-value versus state-of-the-art**

A service oriented end-to-end maintenance architecture and service solution for the legacy fleet operating in the European airspace today, can enable the reduction of the impact of

- Disruptive maintenance due technical faults or performance degradation observed on aircrafts flying
- Scheduled maintenance activities leading to aircraft out of service times

Providing consolidated and relevant information from the flying fleet will allow the operator to intervene and plan maintenance activities before performance degradation and failures cause operational disruptions or maintenance reduces the asset utilization due to aircraft downtime with respect to the flight schedule.

WP3.6 Maintenance will demonstrate the improvements through the integration of new and existing capabilities and the provision of new integrated services enabling:

- Replacement of systematic scheduled maintenance by on-condition maintenance through application of
structure health monitoring (SHM) technologies based on advanced signal, image and data processing for fatigue cracks, corrosion monitoring in combination with enhanced prognostics (algorithms) and conditions based maintenance principles

- System prognostic solutions based on aircraft data
- Technical solutions providing aircraft health status information and diagnostic functions such as functional performance degradation, fault monitoring, data management functions among others

- Improvement of maintenance execution efficiency at turn around and at scheduled maintenance intervals through the integration of remote support functions provided by maintenance control and mobile tools for maintenance execution (e.g. maintenance tools for damage assessment and recording, RFID readers, mobile NDT tools, communication tools, augmented reality and virtual reality capabilities)
- Service solutions supporting the above providing maintenance economic efficiency enhancement through a cross actor (OEM, Supplier, MRO, Airline) value chain driven optimization of architecture and service definition
- The improvement of interconnectivity of all actors to streamline the value chain through a collaborative environment combining multiple data source (aircraft, MROs, OEMs, Suppliers).

The legacy fleet and future aircrafts will benefit in similar ways from the WP3.6 Maintenance deliverables with different extends. Due to the different aircraft technical functions and capabilities

- Close to operation aircrafts (e.g. A350XWB) will provide enhanced aircraft maintenance functions and capabilities leading to a more efficient fleet level service integration and ground based service solutions for maintenance planning and optimization and enhanced maintenance execution
- Future aircraft developments can benefit most by considering services needs as integral part of the product definition providing the highest level of efficiency enhancements and by allowing reducing margins taken in the aircraft design thanks to advanced health monitoring capabilities

The operational and economic impact of an E2E service and value oriented maintenance architecture is strongly depending on the individual business models and operational context of the main actors. In the consequence for a detailed impact evaluation specific operational and business scenarios for e.g. low cost type of operations and legacy type of operations are being developed and provided at the beginning of the project.

On a European Air Traffic level, the impact can be significant. In Europe 5.8% of all flights are delayed due to direct aircraft technical causes and consequential reactionary-rotational delays on subsequent flights. Consequential cost are estimated at 2.8b€ reducing the economic efficiency of the main actors.

- Reducing aircraft technical induced Operational Disruption by 0.2% to 0.5% through Enhanced health monitoring, diagnostics and prognostics solution can provide 133m€ and to 334m€ cost savings per year.
- Reducing the average delay time of 28 minutes by 2 to 4 minutes enabled by enhancements in line maintenance support tools, remote expert support and enhanced diagnostic efficiency can provide approximately 195m€ to 395m€ savings per year
- Depending on the business environment the increased overall aircraft utilization enabled by prognostics and planning optimization provides up to 200m€/year additional profit potential for European airlines

In summary the overall benefit depending on the business environment can be estimated between 530m€ and 930m€ per year.
d) High-level WBS and work-sharing
The WP3.6 WBS accounts the different research streams and demonstrators enabling the WP objectives achievements. The WBS may be modified according to the actual needs of the LPA-IADP program along the selection of core partners and non-core partners in the upcoming call for proposals.

The major CS2 leading partners in WP3.6 are Airbus (up to 18% work share) and Thales (up to 23% work share). The overall major work share will be provided by a consortium constituting out of Large Industries, SMEs and Universities with up to 36%. The remaining 33% of the work share will be provided by additional core partners to be selected in the 1st call for Core Partners in 2014.

The selection of partners is influenced by the demonstration objectives to provide real airline environments. Thus strong emphasis is being taken to ensure the participation of operators in the partner consortium.

It is intended to have the contribution of operators (e.g. airline and MROs) during all phases of the project. It is considered as essential to have real life operational experience inside the project but also to have the opportunity for real life demonstrations in an operator’s environment available. Therefore operators are invited to contribute to all Sub-WPs from the beginning of WP3.6 Maintenance activities.

On some specific topics like certification authority involvement is considered as necessary at a certain stage of the project. OEM partners will provide the certification relevant experience and skills for the Architecture and system definition. Impact analysis is intended to be carried out by independent research institutes with the relevant experience and complemented by dedicated workshops with authority’s involvement.

The partner and consortium set-up is due to change, depending on the final partner contribution and consortium size.

e) Planning roadmap, targeted technology readiness levels
The roadmap for WP3.6 is taking into account the focus on the legacy fleet and short term derivatives emerging in the European market requiring a short time horizon for the achievement of the demonstration objectives.
f) Interactions with *Clean Sky 2* ITDs, IADPs, other interfaces

Maintenance relevant demonstration activities have been identified in Platform 1 WP1.5 “Innovative Flight Operations” of the LPA IADP providing further opportunities for demonstrations beyond 2018. The type of demonstration will depend on the evolution of the demonstrator platforms and detailed demonstration needs for the service oriented architectures. The relevant demonstration objectives will be developed in the course of the definition of the full WP3.6 demonstration needs during the first phase of the activities.
Further exchange on expectations, objectives, deliverables, lessons learned and experience will be established across all Clean Sky 2 domains to ensure a transversal approach and to build and disseminate the foundation provided by WP3.6 Maintenance to achieve the high level vision of maintenance in Clean Sky 2.

Due to the large range of technologies emerging in various research programs such as FP6, FP7 or national funded programs, the integration of results of project as TATEM and VIVACE but also the interaction and exchange with projects as SIMID, SARISTU and OMAHA among others are carefully investigated during the early stage of the project.

g) Budget provisions

The total effort for the full-scope of activities, including the Clean Sky 2 members, Core-Partners, Call for Proposal-Partners and activities through Call for Tender will be in the range of 24 M€ gross (i.e. 12 M€ EU funding required).

The WP3.6 Maintenance activities schedule and budget provisions are driven by the short term R&T needs of the legacy fleet to provide solution for economic efficiency enhancement recognizing their capabilities today and to provide the foundation for future fleet enhancement based on Clean Sky 2 emerging technologies.
h) **Synthesis of added value with respect to H2020 targets**

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology / Activities</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Lead Actors / Key Contributors</th>
<th>ROM EC funding</th>
</tr>
</thead>
</table>
| **D3.6.1 Architecture and Aircraft/Ground IHMM platform** | - Demonstration of the technical feasibility of a service oriented architecture with respect to performance and economic efficiency  
- Demonstration of Aircraft/Ground Integrated Health Monitoring functionalities for the legacy Fleet (incl. diagnostics, configuration/data management/data collection and transfer)  
- Demonstration and Evaluation of the Certification and Security needs  
- Evaluation of E2E service driven architecture performance by comparing business/use cases retained for the design with the merge of all demonstrator results | Reduced Cost of operations by increased asset utilization  
Value oriented services for the main actors leading to increased competitiveness | Reduced number of flight schedule disruptions, arrival on time, seamless mobility, through integrated IHMM and CBM based solutions | 2019 | Thales, Airbus CP Consortium CP (Airlines + SMEs)-TBC | 12 M€ |
| **D3.6.2 SHM solutions and CBM capabilities** | - Demonstration of the operational maturity of SHM Technologies for selected use cases  
- Demonstration of the maturity and performance of Prognostic Methods  
- Demonstration of the maturity and performance of CBM based maintenance task identification integrating enabling diagnostics, prognostics and SHM Technologies | Increased Asset utilization and reduced Cost of operations by increased efficiency in maintenance task execution and task planning as per aircraft needs with minimum impact on aircraft flight schedule | Less aircraft downtime for maintenance due to change from scheduled to planned maintenance  
Reduced number of flight schedule disruptions by performance degradation and failure monitoring and prognosis | 2019 | Airbus CP Consortium CP (Airlines + SMEs)-TBC |
<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology / Activities</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Lead Actors / Key Contributors</th>
<th>ROM EC funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3.6.3 Maintenance Fleet Planning, Optimization and Collaborative Environment</td>
<td>- Development and demonstration of a collaborative IT environment integrating multiple sources of information and providing sufficient resources for the purpose of Data Mining for Maintenance Planning and Performance Optimization Demonstration of the Maintenance planning performance optimization</td>
<td>Increased competitiveness by common rules for information exchange between main actors and value driven services Increased competitiveness through optimized maintenance planning</td>
<td>Seamless mobility by less aircraft downtime for maintenance due to operational planning optimization</td>
<td>2019</td>
<td>Airbus, Dassault Consortium CP (Airlines + SMEs)-TBC</td>
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<tr>
<td>D3.6.4 Remote Support, mobile maintenance execution and infrastructure</td>
<td>- Demonstration of technical maturity of the application for Augmented/Virtual reality solutions and maintenance toolboxes for maintenance execution in an airline environment - Demonstration of maintenance performance enhancement through the application of MCC toolkit for remote support with two ways communication and data link to maintenance using mobile tools - Demonstration of effective integration in the collaborative IT environment of the maintenance execution feedback (mtc. planning, optimization and configuration management)</td>
<td>Reduced Cost of operations by increased efficiency in maintenance task preparation, support and execution Increased Competitiveness through process optimization, common communication rules and function interfaces</td>
<td>Reduced number of flight schedule disruptions through more efficiency task execution during aircraft turn-around and maintenance</td>
<td>2019</td>
<td>Dassault Consortium CP (Airlines + SMEs)-TBC</td>
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### 6.7.9 Synthesis of Added-Value with respect to H2020 Targets by Key Demonstrator

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Lead Actors / Key Contributors</th>
<th>ROM EU funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3.1: Enhanced Flight Operations and Functions (WP3.1)</td>
<td></td>
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<td>2020</td>
<td>Airbus, Dassault, CASA CS2 Leaders Core-Partners (Medium and large Nav-Systems and equipment industry, RE’s) CFP Partners (SME system suppliers, RE’s, academia)</td>
<td>17 M€</td>
</tr>
<tr>
<td>WP3.1.1 Functions for “always easier flight”</td>
<td>Development of functions and solutions, enabling easier control of the aircraft and more accurate navigation</td>
<td>Contributio to less diversion in adverse conditions (fuel savings)</td>
<td>Differentiati g product from the competition</td>
<td>- Safety</td>
<td>as above + EASA</td>
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<td></td>
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<tr>
<td>WP3.1.2 Functions for efficient and easy systems management</td>
<td>Development of functions enabling easier control on on-board systems</td>
<td>N/A</td>
<td>Differentiati g product from the competition</td>
<td>N/A</td>
<td></td>
<td></td>
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<tr>
<td>WP3.1.3 Functions and solutions for man-machine efficiency</td>
<td>Development of pilot monitoring</td>
<td>N/A</td>
<td>Anticipation / ability to propose regulatory evolutions</td>
<td>Safety</td>
<td>as above + EASA and Airlines</td>
<td></td>
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<tr>
<td></td>
<td>Man-machine interfaces</td>
<td>N/A</td>
<td>Differentiati g products</td>
<td>N/A</td>
<td></td>
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<tr>
<td>Demonstrator</td>
<td>Technology</td>
<td>Green objectives</td>
<td>Industrial Leadership</td>
<td>Mobility</td>
<td>Complete by</td>
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<td><strong>D3.2: Innovative enabling technologies (WP3.2)</strong></td>
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<td>2020</td>
<td><em>Airbus, Dassault, CASA CS2 Leaders Core-Partners (Medium and large Nav-Systems and equipment industry, RE’s) CPF Partners (SME system suppliers, RE’s, academia)</em></td>
<td>13 M€</td>
</tr>
<tr>
<td><strong>WP3.2.1 Flexible communication</strong></td>
<td>Radio communication technologies</td>
<td>N/A</td>
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<td></td>
<td>Ability to transfer technology trends into aerospace applications</td>
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<td><em>Contribution to “connected aircraft” solution</em></td>
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<td></td>
<td>Weight/cost → competitive product</td>
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<tr>
<td><strong>WP3.2.2 Aircraft monitoring chain for ground support</strong></td>
<td>Functions and enablers for ground support to the crew</td>
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<td>Enabler for trajectory optimisation (ground based)</td>
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<td></td>
<td><em>Enabler for optimized fleet usage</em></td>
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<tr>
<td></td>
<td>Anticipation of regulatory aspects</td>
<td></td>
<td>Differentiating products and services</td>
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<tr>
<td><strong>WP3.2.3 Avionic components update</strong></td>
<td>Technology bricks supporting new functions and architectures</td>
<td></td>
<td>Fuel saving through weight reduction (equipment + installation)</td>
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<td></td>
<td><em>Weight/cost → competitive product</em></td>
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<td></td>
<td></td>
<td><em>N/A</em></td>
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<tr>
<td>Demonstrator</td>
<td>Technology</td>
<td>Green objectives</td>
<td>Industrial Leadership</td>
<td>Mobility</td>
<td>Complete by</td>
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| D3.3: Next generation cockpit functions flight demonstration (WP3.3) | Cockpit related technologies demonstrated in flight environment | N/A to the flight tests themselves Refer to green objectives of the considered technologies | Ability to demonstrate novel features and get broad exposition thus acceptance of the proposals | N/A to the flight tests themselves | 2022 | - Airbus, Dassault, CASA  
- CS2 Leaders  
- Core-Partners (Medium and large Nav-Systems and equipment industry, RE’s)  
- CfP Partners (SME system suppliers, RE’s, academia)  
- EASA  
- ATC organisation (TBC)  
- Airlines (for in service experiment) | 18 M€ |
| D3.4: Enhanced Cockpit demonstration (WP3.4) | Demonstration of integration of novel functions/equipment in overall cockpit environment | Refer to green objectives of the considered technologies | Ability to integrate novel functions/equipment into incremental development (time to market). Contribution to develop and offer state of the art product in the 1st half of next decade | - Safety  
- Less disruption of operations in adverse conditions | 2020 | - Airbus, Dassault, CASA  
- CS2 Leaders  
- Core-Partners (Medium and large Nav-Systems and equipment industry, RE’s)  
- CfP Partners (SME system suppliers, RE’s, academia) | 14 M€ |
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<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Lead Actors / Key Contributors</th>
<th>ROM EU funding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D3.5: Disruptive Cockpit demonstration (WP3.5)</strong></td>
<td>Demonstration of new cockpit concept: - new crew resource paradigm - integrated cockpit design - functional organisation and architecture - technology enablers (functions, equipments)</td>
<td>1) Benefit coming from overall integration: - fuel saving through end-to-end mission optimisation (on ground/aboard) - fuel saving through major weight reduction (depending on final concept selection) 2) Refer to green objectives of contributing technologies (e.g. noise reduction / approach trajectory optimisation)</td>
<td>- Very strong product differentiating factor (step change) - Anticipation of regulatory aspects</td>
<td>- Safety -Technical prerequisite for crew population and profile evolution (facilitating traffic and fleet growth) - Resilience of operations in adverse conditions (contribution to better service)</td>
<td>2023</td>
<td>- Airbus, Dassault, CASA - CS2 Leaders - Core-Partners (Medium and large Nav-Systems and equipment industry, RE’s) - CfP Partners (SME system suppliers, RE’s, academia) - EASA - Airlines</td>
<td>34 M€</td>
</tr>
<tr>
<td>Demonstrator</td>
<td>Technology</td>
<td>Green objectives</td>
<td>Industrial Leadership</td>
<td>Mobility</td>
<td>Complete by</td>
<td>Lead Actors / Key Contributors</td>
<td>ROM EU funding</td>
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| D3.6 Maintenance service operations enhancement demonstrator (WP3.6) | Demonstration of the technical and economic maturity and performance of a value and service oriented architecture and its enablers:  
- Aircraft/ground IHMM platform  
- SHM solutions and CBM capabilities  
- Maintenance fleet planning and optimization functions incl. collaborative infrastructure  
- Remote support capabilities incl. mobile tools and data and communication means | N/A | Cost of operations reduction by increased asset utilization by change from scheduled to planned mtc., higher task efficiency  
Increased competitiveness through value chain driven services and process opt. | Less flight schedule disruptions, arrival on time, seamless mobility, through enhanced diag./ prog., CBM solutions, flight scheduled oriented mtc. planning, highly efficient mtc. task execution | 2019 | Thales, Airbus, Dassault CP Consortium CP (Airlines + SMEs)-TBC | 12 M€ |

Figure 6.69 – List of demonstrators and respective added values with respect to H2020 targets. A Rough Order of Magnitude (ROM) EU funding is given for each demonstrator. Note that in addition to the listed demonstrators, a budget for project management activities (WP3.0) of 3 M€ EU funding is provisioned.
7 Regional Aircraft IADP

7.1 Going beyond Clean Sky

The Regional Aviation is a key factor for creating resources and an efficient air transport system that respects the environment, ensuring safe and seamless mobility, building industrial leadership in Europe. Regional carriers typically operate aircraft, such as regional jets and turboprops, with fewer than 120 seats, on short to medium-haul routes. The regional aircraft market continues to be a key growth sector of the airline industry and taking into consideration traffic developed by regional aircraft in the last year more than 660 000 millions ASK (Available Seat Kilometer) were offered worldwide. Only in Europe regional carriers were able to offer more than 120 000 millions ASK to passengers, with average distance of 320 NM (about 600 km), slight less than 200 million people in the last year flew on regional A/C within European network. The regional traffic is expected to triplicate in the next 20 years, with a forecast of about 9 500 new regional aircraft to be delivered in the next 20 years (about € 300 Billions, avg. € 15 Billions per year). The growing regional market is currently led by non European actors, with the exception of turboprop manufacturer ATR (50/50 owned by Alenia Aermacchi and EADS). There is a clear and urgent need to invest in developing new technologies in order to recover the global leadership. The integration of innovative and affordable technologies in the future aircraft platforms is a key success factor for manufacturers since it increases appeal and benefits for the customers (both airlines and passengers). The airlines can get significant economic advantages from operating modern aircraft more efficient, eco-friendly, easier and cheaper to manage and maintain, saving money through the reduction of operating costs. The technological improvements have positive impacts on all the items contributing to the total cash operating costs such as fuel burn reduction, reduced maintenance costs, reduced navigation and airport fees due to structural weight saving (innovative aircraft architectures and lighter materials utilization). All these benefits and economic advantages will be even more evident for regional turboprop aircraft that are typically less expensive to operate than the regional jets. The technological enhancements have a significant appeal also on the passengers that can enjoy a better air travel experience thanks to higher comfort and lower noise levels. It becomes clear how the investments in developing new technologies represent a fundamental differentiator for European aeronautic manufacturers in order to maintain or even to increase the competitive advantage on the non-European players. On the next years the technological leadership will gain a more and more relevant role and will contribute to a substantial market share increase in the regional aircraft segment with consequent jobs creation. In a future scenario, characterized by the extensive use of innovative technologies, the regional aviation potential market will increase to more than 10000 units (in the timeframe 2025-2050) and the market share of a new European regional turboprop program will account 30-40%, doubling with respect to the current value.

Regional aircraft basic features are already the key drivers of a dedicated Integrated Technology Demonstrator (ITD) - Green Regional Aircraft (GRA) - within the Clean Sky Joint Technological Initiative financed and running under FP7. Clean Sky GRA is addressing the following success factors of a modern regional aircraft:

- Low weight structural solutions. Scope is to contribute to reduce the aircraft weight -thus fuel consumption and associated environmental impact-, and to simplify structural repairs.
- Low external noise solutions applied to critical items such as landing gear, doors and bays, high-lift devices and specific aircraft configuration to reduce external noise and airport nuisance. The aspect is relevant for regional aircraft because their flight departures and landing are more frequent than larger aircraft in a typical hub
airport affecting then airport noise emission. Also, regional aircraft are able to operate out of smaller urban airports and airport closer to urban areas which are more sensitive to noise.

- Advanced aerodynamics (Natural Laminar Flow wing, turbulent skin-friction drag reduction techniques) and load control to increase aerodynamic efficiency in cruise and off-design conditions (climb, descent), thus reducing engines gaseous/environmental pollutants emission.
- Load Alleviation based on active control of wing movable and passive concepts (aero-elastic tailoring) in order to avoid that gust and manouvre loads may exceed given limits, so as to optimize wing structural design for weight saving.
- All electric solutions are addressed because they potentially improve operative efficiency of on board systems and simplify maintenance and ownership costs so critical for regional aircraft. In turn they contribute to reduce fuel consumption and emissions because electrical systems are more energy efficient and use less polluting materials than traditional solutions.
- Mission and trajectory management is important for regional aircraft because their high take-off and landing rates associated to the relatively slower climbing times have a strong impact on the airport traffic management and in general ATM issues. At the same type available space and costs allowed in regional aircraft is lower than large airliners thus requiring fully compatible solutions at lower volume and cost.

The key technologies of Clean Sky GRA are all coordinated by means of dedicated aircraft configuration analyses and studies performed to compare the different combinations and assess the better solutions. Clean Sky GRA will finally demonstrate and assess those technology potential and performances at system level mainly by means of real scale tests both on ground and in flight.

In Clean Sky 2 the Regional A/C IADP is proposed to bring the integration of technologies/methodologies at a further level of complexity and maturity than currently pursued in Clean Sky. This will be achieved through a comprehensive set of full scale demonstrators, strictly coordinated among them, which will be used to validate, at aircraft level, the integration of technologies for regional a/c matured within this IADP as well as in the Airframe ITD and Systems ITD.

The R-IADP includes activities for the “ecolonomic” structural design and manufacturing of regional aircraft which will be performed in close cooperation with the Eco-Design transversal activities of Clean Sky 2.

In addition to the above, the R-IADP includes activities studies concerning the modification of regional baseline aircraft configuration for:

- Solutions that could be implemented to simplify future repairs and cabin modifications that always occur in service aircraft but that seldom can be considered in the design phase.
- Solutions for other use of the aircraft The related activities intends to take into account operational requirements specific for ground (e.g. life protection, civil security) and sea (e.g. immigration emergency) patrolling. Regional aircraft platform is widely recognized as the main platform for this kind of needs, being turboprop long endurance performance a key element.
7.2 Challenges to be tackled for Regional A/C IADP in the Horizon 2020 Period

- The strategic objectives for regional aircraft research and innovation

The further development and maturation of technologies pursued in Clean Sky GRA at system level requires integration and validation steps beyond what is currently planned in Clean Sky. The actual application of innovative technology in an aircraft as a complex product is pursued only when, as a minimum, the following conditions are met:

- Interfaces and links with the other technologies necessary to the aircraft operation are suitably resolved
- Solutions are acceptable to the market (passenger interfaces and comfort, certification and safety, maintenance process, operating reliability and cost)
- Industrial feasibility is demonstrated to meet the criteria for industrial success for the aircraft manufacturing industry (e.g. competitive non-recurring and recurring costs, and a reliable and competitive supply chain).

[NH(C)5]

The need for a Regional Aircraft IADP in Clean Sky 2 is driven by the necessity to continue addressing the environmental topics and to mature the technologies that will make a real strategic change.

- The challenges for regional aircraft

The strategic objectives for regional aircraft above are consistent with Flightpath 2050, the White Paper on Transport and the ACARE Strategic Research and Innovation Agenda (SRIA). Namely, regional aircraft will contribute to the following challenges:

- Competitive regional aviation will help enable door-to-door journeys within 4 hours’ journey time for 90% of European travelers.
- Innovative regional aircraft will reduce aviation environmental impact offering aircraft suited to the required range and capacity reducing use of overdesigned aircraft on short routes.
- Regional aircraft require little or reduced airport assistance capacity and runway length than large airliners being designed to operate in small regional airports
- They contribute to a fast, safe and effective mobility from less populated or economically developed areas, namely where infrastructures necessary to other transport solutions are not justified by traffic density, severe environmental consequences or high cost.
- Regional aircraft provide a tangible positive contribution to European export and worldwide leadership in the sector.
- Reduction of rational life cycle cost based on an innovative design in which co-simulation of manufacturing, assembly and maintenance is integrated.
7.3 The Role of the Regional A/C IADP (R-IADP)

The role of the IADP dedicated to regional aircraft is to validate the integration of technologies at a further level of complexity than currently pursued in Clean Sky GRA so as to drastically de-risk their integration on future products. Actually, European regional aircraft shall integrate many different technologies and requirements in a product which shall be highly competitive on the performance side and successfully face several international competitors on this market segment.

The regional aircraft market is today shared between European aircraft manufacturers and several non-EU ones. While each aircraft integrator is proposing very advanced and effective aircraft and it is aiming to capture market share, non-EU regional aircraft manufactures are enjoying strong national support for technology development. EU regional aircraft manufacturers need equivalent support to not lose the positive momentum they are experiencing and which is contributing towards recovering the ground lost in recent years.

The Regional Aircraft IADP demonstrations will be built by integrating several advanced technologies and solutions:

- Those from current Clean Sky Green Regional Aircraft and other ITDs
- Those to be matured in the frame of Clean Sky 2 Airframe, Systems, Engine ITDs
- Those matured through other relevant technology development of FP7
- Those to be matured in other relevant H2020 projects
- National projects and company internal projects

Moreover in Clean Sky 2 a more integrated and synergic approach of the R-IADP with the ITDs platforms is pursued, in fact several technological developments will take place in Airframe and System ITDs in strong interaction and collaborative attitude with the other leaders of integrated air vehicles (other IADPs), nevertheless a global steering and management is defined according to the high level work breakdown structure in order to ensure the achievements of final Clean Sky 2 goals for regional aviation.

Figure 7.1 – High-Level Work Breakdown Structure for Regional A/C in Clean Sky 2
Taking into account the outcomes of GRA and considering the high level objectives derived from recent market analysis performed by the Leaders, the strategy is to integrate and validate, at aircraft level, advanced technologies for regional aircraft so as to drastically de-risk their integration on the following future products:

- Near/mid term (in-service from 2022-25 on): Regional Aircraft with underwing mounted turboprop engines,
- Long term (enter in service beyond 2035): Breakthrough Regional Aircraft Configurations, e.g. a/c with rear fuselage mounted turboprop engines

Innovative and highly integrated full scale demonstrations, allowing acceptable risk and complexity but still providing the requested integration answers, are essential to allow the insertion of breakthrough technologies on future regional aircraft products, near/mid term and long term as stated above.

In summary the following demonstration programmes are foreseen:

- **2 Flying Test Beds** (to minimize the technical and program risks), modified existing a/c, TP engine underwing mounted, for demonstration campaigns of: air vehicle configuration technologies, wing structure with integrated systems and propulsion integration, flight dynamics, aerodynamic and loads alleviation, advanced flight controls and general systems, avionics functionalities.
- **5 Large integrated Ground Demonstrators**: Full-scale wing, Full-scale cockpit, Full-scale Fuselage and Passengers Cabin, all including their associated systems, Flight Simulator, Iron Bird. In addition, a Nacelle ground demonstrator will be done in the Airframe ITD.

The Demonstration Programme will be conceptually divided into technologically compatible and “scope close” demonstrations sub-programmes, as follows:
- Flight Demonstration of Air vehicle technologies (done in the R-IADP, FTB1)
- Flight Demonstration of an High Lift Wing, with integrated structural and systems solutions (done in the R-IADP, FTB2)
- Ground Demonstration of the Wing including the airframe and the related systems (done in AIRFRAME ITD)
- Ground Demonstration of the Cockpit (done in the AIRFRAME ITD)
- Full scale innovative fuselage and passenger cabin (done in the R-IADP)
- Flight Simulator (done in the R-IADP)
- Iron Bird (done in the R-IADP; linked to FTB1 scope)
- Nacelle Demo (done in the AIRFRAME ITD)
7.4 Set-up of the Regional A/C IADP (R-IADP)

7.4.1 R-IADP Work Breakdown Structure

The Work Breakdown Structure (WBS) for the Regional A/C IADP is shown hereafter:

Figure 7.3 – Regional Aircraft IADP Work Breakdown Structure and main interfaces with ITDs
7.4.2 R-IADP Management Approach

R-IADP management includes Programme Management, Contracts, Risk Management, Quality, Dissemination, Interfaces management.

In addition to standard WPs leaders, two more management functions are introduced to strengthen the focus on demonstration’s goals and on the other side to reinforce the technologies development control:

- A Program Manager for each Demonstrator
- A transverse Coordinator for each group of technologies linked to relevant demonstrators, called “Waves” (WT), who will ensure technologies developments in compliance with schedule and technical results along the waves and the interfaces among R-IADP and ITDs.

These waves will be developed through technological roadmaps (technology-time-TRL gate) defined to satisfy the high-level requirements of the future High-Efficient Next Generation Regional Aircraft which configuration will be developed at conceptual level in a dedicated work package. To increase synergies and cross-fertilization for technology utilization among the different ITDs and IADPs, the “waves” approach will improve the handling of interactions and interfaces.

The Regional A/C Technologies Developments and Demonstrators are currently arranged along with 8 “Waves”:

- WV1 – ADAPTIVE WING (Liquid Infusion, Morphing, HLD, Winglets, NLF, Drag, High Lift…)
- WV2 - REGIONAL AVIATIONICS (FMS, HMI, Health Monitoring…)
- WV3 - COCKPIT (Advanced composite materials, ergonomy assessment, systems integration, …)
- WV4 - INNOVATIVE FLIGHT CONTROL SYSTEM (Fly-by-Wire, EMA, …)
- WV5 - ENERGY OPTIMIZED REGIONAL A/C (Low Power WIPS, Electrical Landing gears, EPGDS, E-ECS, …)
- WV6 - FUSELAGE STRUCTURE (Advanced composite materials, advanced manufacturing, …)
- WV7 - PAX CABIN (Human centered design, Materials, …)
- WV8 - NACELLE FOR REGIONAL A/C (JET + TP) (Nacelle Materials, Ice protection, Drag Reduction…)

Figure 7.4 – WP0 Principle Work Breakdown Structure

Figure 7.5 – The “Waves” grouping technologies developments for regional a/c linked to relevant demonstrators
The management approach of the R-IADP is schematically represented in the following figure:

The canonic vertical organisation structure has been implemented by toughening horizontal coordination activities, called “waves”, in order to assure project coherence from Technologies Development up to Demonstrations, whereas the Demonstrators Programme Managers call the shots on Waves Coordinators, any time.

The Steering Committee (R-IADP SC) will be participated by CSJU and ITD’s (as permitted non-voting observers) hosting the relevant technologies, so having full visibility of policy and related steering on waves–roadmaps–wave of waves management processes. Furthermore, for each “wave” a Coordinator will assure proper interfaces, interaction and synergies amongst the relevant R-IADP WPs and ITDs WPs. He/She will report to the relevant Demonstrator Programme Manager inside Programme Management Committee (PMC) where decisions at 1st Level WP will be taken or scaled up to SC level when needed. A Master Schedule will contain the “Regional A/C Project” milestones to periodically validate project progress and to take appropriate actions to steer it. Such Master Schedule will include links between project milestones and “wave” developments. Major Milestones will have periodic Projects Reviews where the “main actors” will be relevant Demonstrators Programme Managers, Waves Coordinators, WP’s Leaders and Tasks Leaders.

R-IADP Leader (the Programme Manager) will present the “Waves Status” at the IADP/ITD’s Coordination Meetings chaired by CSJU.

As said to ensure the achievement of the Clean Sky 2 Regional Aircraft objectives a special attention will be given to the definition and management of the Technologies Developments with a dedicated coordinator for each of...
the 8 “Waves” that represents the lines of the main research and development works. In particular, the objective is the definition and monitoring (Verification and Validation phase) of each Technological Wave in terms of:

- Technology Readiness Level (TRL) roadmaps
- Means of Compliance with respect to the definition of each TRL gate
- Technological goals that will be reached
- Process that will explain in which way the Target Analysis will be performed
- Interfaces cross-ITDs.

This technical information will be continuously assessed and upgraded, both in accordance with the Master Plan, and in terms of interfaces among all work packages, various different technological Waves, interactions and interfaces with the technologies developed inside the ITDs that concur to the Regional Demonstration. In particular, the R-IADP management will take care of the correct definition, agreement and achievement of interfaces with other ITDs, with the Technology Evaluator as well as with the Eco-Design transversal activities.

Considering the complexity associated to the challenging integration level and validation objectives of the R-IADP Demonstrators, management and operative models/tools like in an actual modern aeronautical program will be extensively used. So, the objective of this work package is also to define, assure and improve the deployment of an efficient Operative Model in terms of Processes, Methods, Tools/Facilities and Competencies all along the R-IADP Project Life Cycle within a context of Extended Enterprise in collaboration with the other involved Members/Partners. Specific Product design and development sub-processes (e.g. Requirement Management and Development Process, Configuration Management Process) will be identified in order to deploy the related Operative Model in the R-IADP Project in line with State-of-art Concurrent and System Engineering Best Practices.

More specifically, in order to shorten the Time-to-Market, decrease non-recurring costs, reduce risks and create a global leadership essential for a sustainable industrial base in a context of Multidisciplinary and Extended Enterprise the activities will be focused on the following fields:

- Systems Engineering: e.g. for the Requirement Management sub-process the current aircraft manufacturers' best practices will be deployed. The objective is to adopt since the preliminary phases a systematic approach for Requirement Management and Requirement Development process.
- Product Data Management and Configuration Management Process: the current Best Practices based on the PLM Operative Model documented in PLM Procedures and Methods will be deployed and implemented in the selected standard tools
- Virtual Prototyping and Multi-disciplinary Integration: all CAx (CAE, CAD, CAM, etc.) data will be managed and integrated with a multi-disciplinary approach for functional and performance analysis and simulation. The Operative Model will be based on virtual and physical prototyping and simulation platform for data and processes management
7.4.2.1 R-IADP Risks Management

Based upon experience matured with the current Clean Sky GRA ITD, the risk management process will ensure that:

- the Clean Sky Joint Undertaking will deliver, as per Council Regulation dictate, full scale Demonstrators in all areas of research activities, as a result of a fully integrated approach and monitoring of the technological progress and impact.
- IADP’s/ITD’s will deliver aforementioned Demonstrators.
- R-IADP will deliver to CS JU their own flying and ground full scale Demonstrators.
- R-IADP Risks Breakdown Structure and Risk Management Plan will take shape on such waterfall obligations.

R-IADP Risk Management Plan will be an integrated technology Demonstrators oriented plan:

- from Demonstrators (“technologies wave of waves”) to Deliverables (“technology drop of waves”) by responsibilities;
- from Deliverables (“technology drop of waves”), throughout technologies per Demonstrator (“waves”) through technological roadmaps, to Demonstrators (“technologies wave of waves”) by activities monitoring & control.

Therefore, R-IADP Risk Management Organization will assign:

- deliverables risks ownership, to Work Packages Leaders (Deliverables Risk Owner) as Deliverables owners per Work Packages (Deliverables Risk Owner responsibilities: assures the identification and evaluation of the risk event supported by Deliverables Author/s, assures the monitoring and control plan activities, supports the Risk Register update and upgrade, assures WP’s cost-time-performance risks traceability and visibility).
- CfP’s deliverables risks ownership, to Topics Managers (CfP’s Deliverables Risk Owner) as CfP’s Deliverables owners (CfP’s Deliverables Risk Owner responsibilities: assures the identification and evaluation of the risk event supported by the Co-ordinator Risk Manager, assures the monitoring and control plan activities, supports the Risk Register update and upgrade, assures WP’s cost-time-performance risks traceability and visibility).
- Demonstrators risks ownership to Demonstrator Managers. Risk Owner responsibilities: assures the identification and evaluation of the risk event supported by Waves Coordinators and Work Packages Leaders responsible of Deliverables risks, assures the monitoring and control plan activities, issues updates and upgrades the Risk Register, issues, updates and upgrades the Risk Management Plan, supports the Risk Manager to carry out the Risk Management process, retains from Work Packages Leaders the risks data and implementation status of their own responsibility actions.
- Risks management, to Management Committee Chairman (Risk Manager), the Program Leader t (Risk Manager responsibilities: is responsible of risk management process, decides the severity and probability weight, allocates the risks to a Risk Owner, decides the risks items downgrading and rising, assures the monitoring and control activities);
- Risks steering, to Steering Committee (Risk Steering) as Project Steering Body participated by CSJU (Risk Steering responsibilities: steers the Risk Management Plan policy).

R-IADP Risk Management Process, with reference to Resources, Costs, Schedule and Performance/Quality, the process will consists of risks identification, risks analysis/assessment, risks mitigation and risks monitoring/control.
R-IADP Risk Mitigation Plan will retain current Clean Sky policy and so implemented for all high level certified risks

7.4.2.2 R-IADP Foreground Dissemination, Use and Exploitation

Each R-IADP Participant shall ensure that the foreground of which it has ownership is exploited, used and disseminated as swiftly as possible, applying the dictate of Council Regulation (EC) and Grand Agreements to come. R-IADP Foreground Dissemination, Use and Exploitation Plan will take shape on such obligations being all the while compatible with the protection of intellectual property rights, confidentiality obligations, the legitimate interests of the owner(s) of the foreground, and will retain the rules to be stated in the CS JU Dissemination, Use and Exploitation Strategy.

Therefore, R-IADP Dissemination Organization will be devoted to assign:

- dissemination ownership, to Project Leaders (Dissemination Performer) as deliverables owners per Domains competence;
- dissemination management, to Consortium Management Committee Chairman (Dissemination Manager), the Program Leader, being appointed by the R-IADP Coordinator, i.e. the responsible for monitoring the compliance by beneficiaries with their obligations;
- dissemination execution, to R-IADP Coordinator (Dissemination Planner) as R-IADP representative towards the CS JU;
- dissemination steering, to R-IADP Steering Committee (Dissemination Policy) as contractual obligations owners per their own competences.

To comply with Contractual’s obligations, the Dissemination Manager will create, update and manage for due traceability to CS JU:

- R-IADP Foreground Dissemination Plan (PUDF);
- R-IADP Foreground Use & Exploitation Plan (PUEF).
7.4.3 R-IADP Partnerships

- Airframe Manufacturers (OEM) will
  • Conduct the preliminary A/C design studies for the High Efficiency Regional Aircraft;
  • Lead the technologies development activities;
  • Lead the Demonstrators Design and Manufacturing activities, performing the integration, installation work;
  • Perform the demonstrations activities and lead the activities for the analysis of demonstration results.

- Systems / Equipment Suppliers (OEM) will
  • Adapt systems/equipment, solutions for regional a/c on the basis of technologies developments performed by them in the System ITD;
  • Develop Technologies and System/Equipment for regional a/c, as Core Partners in the R-IADP;
  • Support the Demonstrators/Demonstrations activities.

- Engine Manufacturers (OEM) will provide inputs for the studies related to the High Efficiency Regional Aircraft and will ensure the correct interfaces with TP activities within the Engine ITD.

- A Propeller Manufacturer, to be selected as Core Partners, will conduct studies for an advanced low noise propeller and potentially provide solutions to be tested in-flight.

- Research Institutes with large testing facilities will be selected as Core Partners, as well as through CfPs, for IWT, WTT, Thermal Bench, etc.

- SMEs and Academia will be largely involved in technologies development activities as well as in demonstrators relevant activities.

A top-level preliminary identification of activities to be assigned to Core Partners for the R-IADP demonstrators is contained hereafter in the relevant paragraphs.
7.5 High-Level Description of Technologies and Demonstrators

7.5.1 High-Efficiency Regional Aircraft - WP1

I. Generalities

The main objective of this work package is the definition and the sizing of innovative “High-Efficient Next Generation Regional Aircraft” configurations, entering into service beyond 2035, taking into account the Technologies Developments coordinated through 8 “Waves”. These technology waves will be developed through roadmaps to satisfy the high-level requirements of the future “High-Efficient Next Generation Regional Aircraft” and will be applied at aircraft level in order to evaluate the global benefits in terms of green features (emission and noise); in addition to the noise and emissions evaluation, the new dimension, with respect to current Clean Sky, is the particular emphasis given to Lifecycle Cost Assessment estimation and to European industrial leadership competitiveness impact.

A preliminary work-sharing for WP1 “High Efficiency Regional Aircraft” is as follows:

- WP1.1 activities will be performed by the leading Airframe Manufacturers with expected involvement of: Engine Manufacturer Leaders; Propeller Manufacturers as Core-Partners; Other Core- or CfP-Partners will be Research Institutes, Academia and SMEs with background in wind tunnel models and testing;
- WP1.2 activities will be performed by the leading Airframe Manufacturer;
- WP1.3 activities will be performed by the leading Airframe Manufacturer.

a) Innovative Aircraft Configurations - WP1.1

The contribution of this work package will be an airplane design concept to obtain drastic reduction of the global environmental impact and significant Direct Operating Cost (DOC) reduction, adopting innovative solutions resulting from technologies studies and developments. Keeping this objective in mind, the reduction of transport cost (DOC), for instance the maintenance cost reduction, is as important as the environmental impact. Consequently, optimization of manufacturing processes, simplification of maintenance operations, wireless centralized maintenance and system health monitoring will be decision points equally important as the structural technologies devoted to weight reduction & functional improvements.

Figure 7.7 – WP1 Principle Work Breakdown Structure
With respect to the work performed in the current GRA New Configuration Domain, where several regional a/c configurations are studied, the aim of this work package is to perform preliminary a/c design activities for much more advanced configuration of regional aircraft. Starting from a preliminary innovative future regional aircraft configuration, an advanced bleedless Turboprop Engine rear fuselage installation (e.g. tractor configuration as shown), new challenging Top Level Aircraft and New Advanced bleedless Engine Requirements will be therefore defined.

Compared to current regional aircraft as well as to a/c configurations studied in the current GRA, this is an example of breakthrough a/c configuration, which is very challenging due to the installation of the TP engine in the rear fuselage. For this innovative configuration several propeller types (including scimitar even counter-rotating) are being considered. The final selection of the more suitable propeller technology will depend on the engine requirement activity results to be achieved during the project development.

Several other breakthrough regional a/c concept configurations will be studied as well and preliminary a/c design trade-offs will be performed.

Targets for the different technology waves will be fixed under structural weight reduction & functional improvements, aerodynamic improvement, new general systems and avionics capability, internal comfort perspective to Human centered design; furthermore, green powerplant (core engine/propeller) features, including vibration, active control devices and highly integrated systems/nacelle, will be defined.

Based on preliminary sizing and configuration definition loops criteria, the activity will consist in the integration of technological features coming from the other technology waves. The main scope will be to evaluate the improvement, in terms of aircraft performance, green features and life cycle cost assessment due to the single technology. Also the operative costs aspects will be analyzed and trade off studies will be carried out.

The activities in this work package will be performed using tools and methods developed and optimized in Clean Sky GRA as well as new multidisciplinary optimisation methodologies.

The overall concept aircraft design studied in this work pakage will be demonstrated by means of wind tunnel tests.

Furthermore, some features and technologies of the overall concept design studied in this work package will be demonstrated in-flight with the FTB1 and FTB2. These features and technologies will be selected during the development phase according to the feasibility studies and evaluations for their integration on the existing Regional Aircraft that will be selected as demo aircraft FTB1 and FTB2.

All the others technologies related to the overall concept design studied in this work pakage will be validated by means of appropriate methodologies and tools.

b) Top level Aircraft Requirements - WP1.2

The Top Level Aircraft Requirements (TLAR) will be defined selecting guidelines to determine overall A/C performance and environmental targets necessary for deriving the full set of systems/subsystems requirements to design the configuration, size and evaluate the High Efficiency Regional A/C data bases.

TLAR will be based upon a general marketing survey and will provide main parameters needed to design green A/C. The requirements will regard the transport capabilities and in particular will focus on the environmental impact and the life cycle cost without neglecting adequate passenger comfort. Conceptual studies will be
necessary to harmonize marketing requirements and verify technical and feasibility aspects with current and available technology coming from other relevant WP’s. Furthermore, it will be necessary to define certification requirements (current and potential evolution) and requirements of design tools and methodologies for configuration definition.

In general, looking to an innovative configuration layout, the requirements set will be done taking into account these market features:

- Range
- Cruise speed
- Ground performance
- All engine maximum altitude
- One engine out maximum altitude
- Pollution evaluated during all whole mission
- Pollution and noise levels in the airfield domain (annoyance on people around the airport)
- Internal noise

The last three topics will be estimated against an existing aircraft of the same class. Furthermore, the following important features – usually not included in technological assessments – will be analyzed:

- Direct operating costs (fuel, maintenance, airport taxes, etc.)
- Life Cycle costs

Specific attention will be devoted to power plant requirements definition. Therefore, particular care will be given to propeller features analysis (obviously for turboprop engine). In this way, it will be possible to have a clear idea about engine source noise and mainly information about induced vibration in passengers’ cabin.

In a similar way, a Top Level Aircraft Requirement will be established for the Regional A/C operations optimized for short point to point flights, connecting airports with short runways, which technologies will be tested in FTB2. This TLAR will be one of the first activities to be performed in CS2. Once these top level requirements are established, the configuration definition of the A/C technologies will be defined in line with this TLAR, as a previous step for the detailed design in the Airframe ITD.

c) **Technologies Requirements - WP1.3**

Regarding technologies studies, this work package will provide initial targets to be applied to single technological aspects:

- Structural weight reduction & functional improvements
- High speed efficiency and low speed requirements
- On board systems features
- Minimization of the life cycle cost

The technologies requirements will be updated in accordance with the preliminary a/c design configuration loops and will be related to the following main areas:
Figure 7.8 – Regional A/C main areas requiring technological development

Selected technologies and features of the overall aircraft concept design defined in this work package will be demonstrated with the Ground and Flight demonstrators. These features and technologies will be selected during the development phase according to the feasibility studies and evaluations for their integration on the demonstrators.

II. Planning roadmap, targeted technology readiness levels

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<td>4 WTT for Aero-acoustic validation</td>
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<td>5 ECDs for Concept Aircraft Simulation Models to TE (Major Deliverables/Milestones)</td>
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<td>Preliminary TRL Roadmap for Aero-acoustics of a breakthrough Regional Aircraft Configuration</td>
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ECD = Estimated Completion Date
III. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

This work package has continuous interaction and interfaces with the R-IADP WP 2 “Technologies Development” as well as the HVCE Airframe ITD B activity line where once several technology concepts have been defined, they will be developed and manufactured, taking into account the synergies created in that ITD. Its activities will take into account the outcomes of the Clean Sky GRA New Configurations Domain.
## IV. Synthesis of added-value with respect to H2020 targets

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Lead Actors</th>
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<tr>
<td>WTT for Configuration of Next Generation Hi-Efficient Regional A/C</td>
<td>Innovative configuration, advanced powerplant integration, efficient technologies insertion at A/C level</td>
<td>-10 / -15% CO2 -10 / - 15% NOx -3 / - 6 EPNdB (These include individual tech’s contribution as well as engine contribution) All above targets are to be considered w.r.t. Clean Sky GRA (TP 90 concept a/c for 2020 year) achievements in 2015) achievements in 2015</td>
<td>To maintain the European leadership in regional aircraft design, integration, maintenance and recyclability of new advanced and disruptive systems</td>
<td>Fuel efficiency Noise abatement STOL Reduction of costs of transport (DOC)</td>
<td>2020 (TRL5)</td>
<td>ALENIA, EADS-CASA / Engine Manufacturers; Propeller Manufacturer as Core-Partner and others (Research Institutes / Universities with background on WT models and test) as Core-Partners or CfP-Partners</td>
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*Clean Sky 2 Joint Technology Initiative in Aeronautics*
7.5.2 Technologies Development - WP2

I. Generalities

The individual Technologies Developments for Regional A/C are arranged along with 8 “Waves” and several individual roadmaps which will be developed in synergy with other ITDs, in particular Airframe ITD and Systems ITD. The WBS for technologies development within the R-IADP is the following:

![Figure 7.9 – WP2 Principle Work Breakdown Structure]

The starting point for the work to be performed in each of the above work packages will be the development of relevant technologies achieved in the current Clean Sky GRA ITD. These technologies will be further developed with the aim to achieve much higher integration and validation levels. Other technologies, including the ones from FP7, H2020 L2 projects and National Projects will be considered as well.

For each sub-work package, specifics and dedicated periods of review, development and technology down selection for all demonstrators, as shown in the schedule of paragraph 7.5.2(II), will be performed so that the selected technologies will be the ones than can really achieve the necessary TRL level in time for the ground and flight test demonstrations. The activities performed in these work packages have the main scope to take technologies for which there is a very high-level of confidence in achieving a satisfactory level of maturity under Clean Sky 2 so as to be integrated together with other interfacing technologies on the large-scale demonstrators of the R-IADP.

i. Adaptive Electric Wing - WP 2.1

These wing technologies for regional a/c will be developed in the R-IADP as well as in the Airframe ITD. The related wave management will contribute to assure a strong synergy between the R-IADP and the Airframe ITD.

Main objective of this work package is to further develop and mature the integration of wing technologies for future green regional aircraft, featuring advanced performances (high aerodynamic efficiency, load control & alleviation functions), low noise impact, innovative low-weight structural design, so contributing to a drastic reduction of the environmental impact of air transport over next decades.

All the Overall Aircraft design activities devoted to the definition of the wing to be tested in FTB2 will be performed in these WPs, providing all information needed to design and manufacture the components inside the ITD Airframe.

Main wing technologies developed in the R-IADP are organized as per the following preliminary work breakdown structure:
A preliminary work-sharing for WP2.1 “Adaptive Electric Wing” is as follows:

- WP2.1.1 activities will be mainly performed by Core Partners (Wing structural components manufacturers, materials providers, SME, Research Institutes and Academia); the leading Airframe manufacturer will be involved for the requirements, activities follow-up and interfaces with the other work packages; other partners will be involved in specific items through CfPs.
- WP2.1.2, WP2.1.3, WP2.1.4, WP2.1.5, WP2.1.6 activities will be mainly performed by Core-Partners (Universities, Research Institutes, SME, etc.); the leading Airframe manufacturers will be involved for the requirements, activities follow-up and interfaces with the other work packages; other partners will be involved in specific items through CfPs.

a) **Innovative Wing Structure D&M (Design & Manufacturing) - WP2.1.1**

Starting from the outcomes of *Clean Sky* GRA LWC Configuration, manufacturing of an outer wing for regional a/c (TRL 5), this work package will be devoted to the developments, verification and optimization of the liquid infusion technology for stiffened panels manufacturing so as to allow its application in the production of parts with a quality and performance standards suitable for in-flight real-scale demonstrations.
Such work will be performed in close coordination with the Eco-Design transversal activities so as to optimize the Liquid Resin Infusion (LRI) process for a green "economic" fabrication of Regional AC wing stiffened panels by low (Out of Autoclave -OoA) energy curing.

The expected benefits that will be addressed from the introduction of the liquid infusion technology for the manufacturing of the composite stiffened panels of the wing box consist in the reduction of the manufacturing costs, in the improvement of automated manufacturing processes and in the improvement of the environmental aspects if compared to a traditional pre-preg lamination process. Other aspects dealing with structural enhancements due to thermoplastic use could be implemented if appropriate level of TRL is reached.

Development, verification and optimization of suitable advanced technologies & materials for the manufacturing of the wing box components, as ribs, spars, clips, etc., aimed to the reduction of the manufacturing costs and the improvement of the environmental aspects if compared to a traditional process.

Principal structural elements SHM/NDI and wires Health Monitoring.
Development of an high automated process for the assembling of the Wing Box components in order to achieve a significant reduction of the manufacturing costs and timing.

Rational Engineering AC Life Cycle methodology development: it addresses rationally an integrated process for the life cycle management at Aircraft level capable to take advantage from the simulation of: Testing, Manufacturing, Assembly and Service Life. The approach is addressed also to the integration of design methodologies and technologies developed in Airframe ITD WP B-4.3 in a unified methodology running on High Performance Computers (HPC).[NH(C)8]

b) Morphing Structures - WP2.1.2

Advanced architectures will be developed to be adopted as wing control surfaces (small trailing edge devices / mini tabs / adaptive winglet) for loads control function and/or innovative high-lift devices (smart droop nose, morphing flap) in order to achieve lighter and simplified actuation/kinematic systems. Key technology for these architectures will be morphing structures relying upon compliant mechanisms or Shape Memory Alloy based actuation concepts. A correlated and necessary technology that shall be also developed is the actuation system and relevant electronic control.

Morphing structures have been investigated within a large number of research activities over past decades. Morphing wings matching the optimal aerodynamic shape at any flight condition is the most challenging aeronautical application of such technology. Current projects (Clean Sky - GRA and SARISTU) will provide technology maturation (TRL 4/5) for the structural-mechanics and materials aspects, including full-scale limited experimental validations. The adoption of morphing control surfaces and their validation in an operational environment through fly testing therefore represent a step forward, looking at potential application of such technology to innovative green airliners.

c) Advanced HLD (High Lift Devices) - WP2.1.3

Advanced highly-efficient low-noise HLD will be developed by considering especially architectures suitable for a NLF wing, in order to increase A/C high-lift performances in take-off and approach/landing conditions, and to reduce A/C community noise in approach/landing flight phases. The achievements from Clean Sky - GRA ITD (TRL 4/5) will form the basis for the concerned further development of HLD technologies.
Droop nose and morphing flap will be the HLD concepts considered first, as alternative solutions to conventional leading edge and trailing edge systems. Such architectures will be especially taken into account for application to a NLF outboard wing designed for a future TP regional A/C. An important aspect that shall be also considered is the actuation system and the relevant electronic control.

d) Load Control & Alleviation (LC&A) - WP2.1.4

Load Control & Alleviation (LC&A) technologies will be developed for a dual purpose: i) to optimise spanwise load distribution (LC function) so as to improve aerodynamic efficiency in all flight conditions, and ii) to avoid that wing bending and torsion moment from gust and/or manoeuvre loads may exceed given limits (LA function), thus optimising the wing structural design for weight savings. The work will include the following elements:

- Conceptual aero-mechanical design (sizing and settings) of conventional (used in unconventional way) / unconventional devices for loads control (mini-tabs, mini-TED, morphing trailing edge flaps) and load alleviation (ailerons / split ailerons, movable winglet).
- Conceptual design and structural integration of respective actuation system, considering system enhancements to cope, in larger and better extent, with dynamic load and aeroelastic effects.

The results of technological studies, validated by WT tests on aero-elastic and aero-servo-elastic wing models, and ground control system testing carried out in the frame of Clean Sky – GRA ITD project will represent the key elements for further development of the technical solutions for LC&A functions and their future application to green regional aircraft. These results will be extended by means of further aerodynamic, aero-elastic, structural analysis and relevant ground experimental validations dedicated to scaling the developed concepts to the selected CS2 FTB configuration and to define the relevant performances level.

e) Wing NLF (Natural Laminar Flow) - WP2.1.5

Aerodynamic design of a Natural Laminar Flow (NLF) wing tailored to a future Turbo-Prop Green Regional A/C to reduce drag / enhance aerodynamic efficiency at cruise conditions will contribute to reduce A/C fuel consumption / gaseous emission. NLF is a mature technology which proved, from several flight tests in the past, to be able of providing large reduction (up to 10%) in the A/C drag.

Development of a NLF wing design sized to a TP regional A/C represents a breakthrough toward next-generation green air transport. By taking into account the presence of wing-mounted propeller engines, only the outboard panel of the wing will be designed to be laminar; this part (from the kink/nacelle station to the wing tip) is, however, a large portion of the total wing surface.

Achievements / lessons learned from theoretical and experimental activities carried out in this field in the frame of Clean Sky GRA ITD programme, namely design and WTT validation of a NLF wing for a future 130-seat rear engine regional A/C, will be the basic know-how for the concerned technology development.

f) Drag Reduction - WP2.1.6

WP2.1.6 focus on the development of innovative devices for turbulent skin friction drag reduction in all flight conditions, and innovative coatings to avoid contamination issues on laminar wings, therefore preserving low-drag performance at cruise design point.

Innovative aerodynamic concepts (say 3D-riblets) and new manufacturing techniques will be exploited, by evolution of results from Clean Sky GRA ITD, in order to realize advanced riblets films to be applied to the A/C external surface.
For the WP2.1 interfaces and interactions with the Airframe ITD WP B-2.3 “High Lift Wing” are very important. In fact, within the Airframe ITD, different technologies depicted above and explained in detail in the Airframe ITD Chapter, will be developed to the degree of maturity required to be then later integrated to a Flying Demonstrator and flight tests in the IADP. The objective will be to develop advanced technologies for regional aircraft high lift wing, increase the lift performance of the overall wing at low speed focusing on larger wing aspect ratio, advanced structural architecture including systems integration and more integrated torsion box manufacturing process with more efficient and advanced materials. In addition, more accurate analysis methods, allowable determination, and certification approach will be developed.

The following wing technologies for regional aircraft will be developed:

- Advanced Structure concepts, manufacturing and testing
- Wing Leading edge Morphing – including actuation by EMAs providing the basis for the integration of anti-ice systems
- Winglets morphing - structural devices that might be optimally adapted to different flight conditions through relatively minor shape alteration induced by relative displacement of trailing edge.
- Adaptive High Performance high lift devices
- Drag reduction including Improved laminar flow
- Active Load protection
- Improved high wing nacelle and power plant integration
- Aileron control through innovative secondary system devices

These technology developments will be coordinated and harmonized within the IADP Wave 1.

ii. Regional Avionics – WP2.2

The aim of this work package is to address the technologies related to Avionics for regional aircraft. The main target benefits of technologies are:

- Safety
- Operational cost
- Certification

The starting point of this work package will be the technological solutions, common for all platforms, that will be developed in Systems ITD. Starting from the above common solutions, regional specificities (e.g. HMI, regional a/c constraints and capabilities) will be identified in order to customize them for New Generation Regional a/c.

The technologies development will be articulated as per the following preliminary work breakdown structure:
A preliminary work-sharing for WP2.2 “Regional Avionics” is as follows:

- WP2.2.1 activities will be performed by the leading Airframe Manufacturers and System Leaders;
- WP2.2.2, WP2.2.3 will be mainly performed by the leading Airframe Manufacturers, Systems Leaders, and others (e.g. Equipment Manufacturers, SMEs, Universities, Engineering Organizations, etc.) as Core- or CfP-Partners.

a) **Avionics Functions - WP2.2.1**

Regarding the Avionics Functions, the main technology that will be considered for Regional A/C is the Flight Management System New Generation (FMS NG). Starting from the technological solution developed in the Systems ITD, in the R-IADP, the FMS NG will be customized to regional a/c purposes taking into account specificities in terms of mission profile and airline needs. It should be noted that this FMS NG will include Green Functions pursued in *Clean Sky*. The above solution will take into account new ATM constraints (SESAR, NextGen).

b) **Innovative Flight Deck - WP2.2.2**

The innovative flight deck technologies will enable the cockpit to be more flexible and customizable based on peculiar HMI requirements for regional aircraft due to:

- Specific avionics functions defined in WP2.2.1
- Aircraft space constraints

The innovation will explore different fields, e.g.:

- Pilot interaction (e.g. multi-touch, haptic, voice)
- Data fusion
- Data format presentation

Such new concepts will be defined in order to address safety, pilot workload reduction and situation awareness enhancement. The reduction of the workload and the provision of a better assistance to the pilot in critical
situations are considered a key capability to be developed in order to pave the way for single pilot operations. In addition, the aforementioned capability would deliver a safety improvement also on traditional two-pilot operations, helping the crew to cope with the modern aircraft systems complexity, especially during abnormal conditions.

c) Performance and Health Monitoring - WP2.2.3

Performance and Health Monitoring studies will start from studies addressing:

- on-board Health Monitoring architectures;
- integration of HM in Avionics and interfaces with the Enhanced Electrical Energy Management (WP 2.3.4) and Structural Health Monitoring (WP 2.1.1 and Airframe ITD WP B-4.3);
- collection methods of Performance / Health Monitoring data from all involved systems (e.g. general systems, avionics, structures, flight control systems);

A Performance and Health Monitoring advanced model will be set up and tested. Its main functions will be:

- to collect information from relevant a/c systems;
- to filter a limited amount of data for real time monitoring purposes;
- to store a large amount of data for on ground analysis;
- to provide data fusion capability using different types of sensors.

This model will be used for two purposes:

- Real-time, as a support to pilot’s operations: a subset of data will be aggregated and real time compared to theoretical a/c models in order to identify anomalous conditions (e.g. Extended Aircraft Performance Monitoring). In case of any occurrence, an adequate level of information will be provided to the pilot to support his operations. The main aims of real time analysis is to increase safety and to reduce pilot workload, supporting his decisions during flight, especially in critical situations. And for this purpose, these functions will take large advantage of New Generation of cockpit (e.g. new concepts, new interactions).
- Off-line, for on ground operations: The complete set of data will be collected/managed in order to be provided to ground operators, mainly for maintenance/monitoring purposes. In this topic regional airline specificities will be considered.

iii. Energy Optimized Regional A/C – WP2.3

The aim of this work package is to address technologies related to innovative on-boards systems for regional aircraft through a strong synergy between the R-IADP and the Systems ITD.

With respect to current Clean Sky, further development of the innovative technologies for aircraft systems, effectively improving the overall aircraft energy efficiency, but also drastically reducing the current environmental impact in terms of noise and pollution will be pursued. In particular, the energy optimized solutions for Electrical Power System as well as the electrically powered solutions for on-Board Systems will be assessed: they enable the application of the All electric A/C concept and in turn the engine efficiency/fuel consumption but also they simplify the maintenance and ownership costs, so critical for regional aircraft. Furthermore, they use less
polluting materials than traditional solutions. As matter of fact this work package aims to study and develop technologies for future regional Aircraft as per the following preliminary work breakdown structure:

A preliminary work-sharing for WP2.3 “Energy Optimized Regional Aircraft” is as follows:

- WP2.3.1 activities will be performed by the leading Airframe Manufacturer interfacing with Equipment Manufacturer acting as Core Partner in the System ITD (to be confirmed); Core or CfP Partners for IWT activities will be involved;
- WP2.3.2 activities will be performed by the leading Airframe Manufacturer interfacing with System Leader in the System ITD; Core or CfP Partners will be involved especially for Nose Landing Gear activities;
- WP2.3.3 activities will be performed by the leading Airframe Manufacturer and Systems Leader; Core or CfP Partners (Research Institutes, Academia, Equipment Manufacturers, Engineering Organization) will be also involved;
- WP2.3.4 activities will be performed by the leading Airframe Manufacturer interfacing with System Leaders in the System ITD for Electrical Power Generation, Conversion and Distribution; Core or CfP Partners will be also involved;
- WP2.3.5 will be performed by the leading Airframe Manufacturer and Systems Leader;
- WP2.3.6 are expected to be performed by a Propeller Manufacturer as Core Partner;
- WP2.3.7 activities will be performed by the leading Airframe Manufacturer interfacing with Equipment Manufacturer acting as Core-Partner in the System ITD (to be confirmed); CfP-Partners might be involved for specific topics;
a) **Low Power WIPS (Wing Ice Protection System) - WP2.3.1**

Taking into account *Clean Sky* results, the objective is to develop a low power consumption wing ice protection system for regional aircraft. In the initial phase of the project, a trade-off will be conducted to define the optimal WIPS technologies to be developed. The technology integration development plan for the selected technologies will include key milestones to monitor its maturation steps as well as a decision gate for the in-flight demonstration.

To achieve the low power requirement for regional a/c, the following technologies will be considered:

- hybrid electrothermal/electromechanical system
- fully electromechanical system, including electrothermal parting strips

Such technologies are expected to be developed by a Core-Partner within the System ITD (to be confirmed after the selection process).

IWT Test Campaigns will target the verification of the system configuration optimisation in terms of power consumption, exploiting the flexibility of the actuators/mats distribution over the protected surfaces and the cycling sequences, and the integration verification on the Regional A/C wing. The IWT Test Campaign will contribute to reaching TRL 5 for the selected IPS technologies. A decision will then be made to determine whether IPS flight tests should be performed on the Demonstrator outboard wing contributing to reach TRL 6. The IWT preparation activity will be conducted with the contribution of a Core- or CfP-Partner.

b) **Electrical Landing Gear System including “Green” taxing - WP2.3.2**

The main objectives are: i) study of fully electrical Landing Gear Concept, body gear configuration, for weight saving, noise reduction and further benefits in terms of hydraulic removal and maintenance; ii) design, development, manufacturing and integration testing of the selected prototype Enhanced Electrical Landing Gear System (EE_LGS) for full scale ground test, including: Main Landing Gears, Nose Landing Gear, Lock/Unlock mechanism and doors, Electrically actuated Extension/Retraction System, Electrically actuated Steering System, Provision for electrically actuated Braking System, Electronics Control Units, System for “Green” Taxing.

c) **Thermal Management - WP2.3.3**

For thermal management, new concepts will be developed for improved thermal load management. Aircraft components, systems or equipment, will integrate innovative cooling technologies and products so as to reduce the overall power consumption used for active cooling of the systems and improving the physical distribution of the heat dissipated in the aircraft to better balance heat and sinks.

Starting from existing studies carried out under EU projects such as PRIMAE, POA, MOET as well as *Clean Sky*, the following thermal technologies will be considered:

- Cooling strategies exploiting integration at aircraft level which use diphasic loops (heat pipes, loop heat pipes), liquid cooled heat sinks (embedded cold plates), mini VCS for complete E/E bay closed loop cooling;
- Alternative aircraft heat sinks solutions (fuel tank, external flow, water waste, etc.);
- Heat exchangers (high-efficiency metallic foam etc.).
The WP activity will be linked to the Systems ITD (see related paragraph on “Next Generation EECS Demonstrator for Regional A/C”).
The contribution of either Core- or CfP-Partners is also foreseen. Involvement are envisaged on specific topics such as High-efficiency Heat Exchangers, Heat pipes/Loop Heat Pipes Mini VCS, including component manufacturing.

d) **Advanced EPGDS (Electrical Power Generation and Distribution System) - WP2.3.4**

- **Advanced Electrical Power Generation and Conversion System (EPGCS)**

The main objective is to further develop those investigations for aircraft HVDC power network with the target to continue the demonstration of the feasibility of an all-electric EPGCS configuration applicable to the Future Regional Aircraft. Also starting from *Clean Sky* outcomes, activities will be carried on with respect to:

- System architecture requirements definition;
- EPGCS equipment integration;
- System modeling and simulation;
- Assessment/validation of demonstration results.

Technologies development/maturation will be assessed in conjunction with equipment suppliers within Systems ITD, while ground demonstration will be possibly performed on integrated large scale electrical test bench (GETI and/or possible re-use of *Clean Sky* Copper Bird) in the Systems ITD.

- **Advanced Electrical Power Distribution System with Enhanced Electrical Energy Management**

The main objective is to design and develop an innovative strategy for a highly decentralized, modular and flexible smart EPDS with solid state based secondary distribution modules being able to:

- Relieve or "reconfigure" itself by switching in case of overload or faults;
- Mutualize distribution parts between different loads;
- Assess its health in real time;
- Protect dynamically load wiring and components;
- Mix communication and power transmission architecture.

In addition, the EPDS will be equipped with Enhanced Electrical Energy Management (E2-EM) functionalities. Starting also from *Clean Sky* outcomes, activities will be carried on with respect to:

- System architecture requirements definition;
- EPDS equipment sizing;
- System modeling and simulation;
- Assessment/validation of demonstration results.
e) Electrical ECS (Environmental Control System) - WP2.3.5

Starting from Clean Sky results, a review and optimisation of E-ECS architecture for the Regional Aircraft will be performed. A trade-off will be conducted to define the optimal E-ECS architecture with respect to system impact on a/c life-cycle costs (weighted over parameters such as weight and power consumption, reliability, drag increase and enhanced engine power efficiency). The selected architecture configuration will be used as reference for development of an E-ECS Demonstrator to perform Laboratory Test and support the development of the Thermal Bench.

In addition to Clean Sky E-ECS technologies (e.g. Motorized Turbocompressors, Power Electronics), the WP will address the integration of key technologies such as Heat Exchangers, Power Electronics cooling systems, Vapour Cycle Systems, Humidifier / dehumidifier. Cabin comfort aspects will be investigated: temperature control, humidification / dehumidification. The integration of E-ECS Demonstrator (to be developed in the Systems ITD, sized for regional a/c 90 pax) into the Thermal Test Bench in the framework of Fuselage/Cabin Integrated Demonstrator will verify capability of E-ECS to achieve performance target in terms of environmental control and its integration with cabin thermal behavior.

Thermal Tests on E-ECS Demonstrator will contribute to reaching TRL 5 for E-ECS for Regional Aircraft.

This WP is strictly linked with the Systems ITD (see paragraph related to “Next Generation EECS Demonstrator for Regional A/C”). Involvement of additional partners is expected through CfP on specific topics such as air Intakes protection.

f) Advanced Low Noise Propeller with Innovative Ice Protection System - WP2.3.6

As an objective, a Core-Partner will be selected to investigate a Propeller for regional aircraft capable to significantly reduce the external noise which the most critical area for the environmental targets of regional aircraft.

Both Near Field and Far Field Noise propagation will be investigated in order to:
- reduce source noise entering the cabin through the Fuselage during all the Cruise conditions;
- reduce propagated noise on ground during take-off procedures.

Furthermore, a study will be performed and technologies developed for Autonomous Ice Protection System and its integration in the advanced propeller.

g) Enhanced Fuel System & Inerting - WP2.3.7

Studies and development of technologies for innovative fuel system/equipment. Such technologies will be developed in conjunction with the innovative wing configuration and, in accordance with the achievements of their maturation level, they might be included in the R-IADP Flight demonstration programme.

Studies and development of an Active Fuel Tank Inerting System (AFTIS). A trade-off will be conducted to define the optimal AFTIS architecture with respect to system impact on a/c life-cycle costs (weighted over parameters such as weight, power consumption, reliability, useful life and efficiency). The selected architecture configuration will be used as reference for the development of an AFTIS Demonstrator to perform Laboratory and Flight Tests.
iv. **Innovative Flight Control Systems - WP2.4**

The high-level objective is to replace on Regional Aircraft all or part of the hydraulic systems that feed the flight control system with lighter and simpler electrical systems offering unchanged reliability and performances. This goal, justified by economical and environmental constraints, will be more energy-efficient if the different aircraft systems will be managed in an integrated way, overcoming the ATA concept.

A technological study correlated with this architectural configuration will consider the Electro-mechanical Actuation System. This study shall also focus on the ways to meet the relevant safety requirements, and fit alternatives actuation concepts on secondary system.

Another aspect that will be analyzed is the implementation of load control/load alleviation systems, involving dedicated sensors and new aerodynamic devices or conventional control surfaces also actuated with innovative means.

The development of main technologies will be articulated as per the following preliminary work breakdown structure:

![Figure 7.13 – WP2.4 Principle Work Breakdown Structure](image)

A preliminary work-sharing for WP 2.4 “Innovative FCS” is presented as follows:

- WP2.4.1 activities will be performed by the leading Airframe Manufacturers, System Leaders and other players (e.g. Equipment Manufacturers, SMEs, Universities, Engineering Organizations, etc.) as Core- or CfP-Partners;
- WP2.4.2 activities will be mainly performed by System Leaders and other players (e.g. Equipment Manufacturers, SMEs, Universities, Engineering Organizations, etc.) as Core- or CfP-Partners; the leading Airframe Manufacturers will be involved in the requirements, equipment development follow-up and interfaces with other work packages.
a) **Advanced Fly-by-Wire - WP2.4.1**

Studies and technologies development will be performed for:
- Advanced and affordable flight control system architecture for regional A/C
- Load control and Load Alleviation System (sensor, control laws and actuation for new aerodynamic devices/conventional control surfaces actuated also in unconventional ways)

b) **EMA (Electro-Mechanical Actuation) - WP2.4.2**

The following technologies for EMA will be investigated, also continuing the work performed in the current *Clean Sky 2* Programme:
- More reliable electromechanical assembly able to overcome typical failures (mechanical jamming, motor coils failures, etc)
- Embedded compact power electronics with higher power density and operative in a harsh environmental conditions
- Health monitoring capable to reconfigure the system following an actuation degradation/failure
  Architectural trade off among different actuator configurations (EMA synchronization for secondary FCS, redundant EMA acting on the same surface)
- Hingeless surface actuation system taking advantage of the new composite structure flexibility.

EMAs of different types will be developed for the different flight control system devices developed. Micro EMAS for Leading edge actuation, winglet morphing actuation will be implemented at different stages through the Airframe ITD (for ground demonstration) and R-IADP (for flight demonstrations)

**II. Planning roadmap, targeted technology readiness levels**

As shown in the following picture, for each work package, in the first phase of activities, the results of relevant domains of GRA ITD, will be taken into account. Based on these results and considering also other candidates technologies a period will be dedicated for review, assessment and down selections of technologies that are evaluated to be capable to reach the necessary TRL level for the integration on relevant demonstrators. Then, the technologies development and their maturation will continue up to the achievement of TRL4 for integration on Ground Demonstrators and TRL5 for integration on the Flight Demonstrator.
NOTE: Above TRL Gates are related to the technologies integration for regional aircraft and, they therefore also include the specific adaptation work to be performed in the R-IADP when needed.

III. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

The **WP 2.1 Adaptive Electric Wing** will rely upon relevant major achievements of Clean Sky – GRA ITD WP2 “Low Noise Configuration Domain” and WP1 “Low Weight Configuration Domain”. Within the R-IADP, various wing technologies will be demonstrated in flight by means of the Regional Aircraft Flying Test Bed - FTB #1 & FTB #2. A strong link with WP3.1 & WP3.5 therefore exists. Interactions with design methodologies and technologies developed within Airframe ITD WP B-4.3 also exist.

Furthermore, as preliminary results of interactions with Systems Leaders, the WP 2.1.2, WP 2.1.3 and WP 2.1.4 are linked with the System ITD WP 3.2.1.

The **WP 2.2 Regional Avionics** is strongly linked with Clean Sky GRA ITD WP4 “Mission and Trajectory Management” as well as with SGO ITD WP3.5. The main interfaces and interactions will be with the Systems ITD: the overall approach is that in the Systems ITD, activities common for all platforms are pursued, while in R-IADP customization to regional application will be covered. Based on this idea, each avionic technology studied in R-IADP has a link with a WP in the Systems ITD.

Within the Airframe ITD a Full-Scale Cockpit demonstrator will be developed. Inputs and technology developments from the Systems ITD will also be incorporated to the IADP Technology Waves as they mature to be integrated with the Airframe and with the Aircraft to be finally flown in the Flying Test Bed#2.

Main interfaces with the Systems ITD are envisaged with the following work packages:
WP1.2 “Flight Management”
WP1.3 “Advanced Functions”
WP1.1 “Cockpit Display Systems”

In addition, preliminary discussion between the R-IADP (Alenia) and the Systems ITD (SAFRAN) on Health Monitoring topic already took place. For the time being, there is a common interest on the topic.

The WP 2.3 Energy Optimized Regional A/C is linked with Clean Sky GRA WP3 All Electric Aircraft and SGO WP2 Management of Aircraft Energy. Within the R-IADP, it is linked with the following work packages:

- WP1 “High Efficiency Regional Aircraft”
- WP3.1 “FTB#1”
- WP3.2 “Fuselage/Cabin Ground demonstrator”
- WP3.4 “Iron bird”
- WP3.5 “FTB#2”

Interfaces and strong interactions are foreseen with the Systems ITD. From coordination among RA-IADP Leaders and Systems ITD Leaders, cross-links between the IADP and ITD have been preliminarily identified as cross-referenced in the JTP WPs. The following table summarizes the identified cross-links between the Systems technological waves in R-IADP and the advanced technologies in Systems ITD with indication of the expected final demonstrator. A Technology Roadmap of the items developed in Systems ITD, in particular the ones expected to be tested on FTB to mature TRL 6, will be detailed and agreed with relevant ITD System members.

The decisional process will be based on the assessment of the TRL progressive gates to be reached by the technology in accordance with its maturation process.

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Interfaces with the Airframe ITD are also anticipated and concern WP B-4.3 “More Affordable composite fuselage”, WP B-3.3 “Highly integrated cockpit” and WP B-4.4 “Affordable low weight, human centered cabin”.

The **WP 2.4 Innovative FCS** is linked to *Clean Sky* GRA:
- GRA WP2 “LNC - Load Control/Load Alleviation part”
- GRA WP3 “All Electrical Aircraft/More Electrical Aircraft”: EMA (E-Rudder) Cfp

Main Interactions within the R-IADP WPs concern the following work packages:
- WP2.1 “Wing”
- WP3.1 “FTB#1”
- WP3.4 “Iron bird”
- WP3.5 “FTB#2”

Finally, interfaces and strong interactions with the Systems ITD (WPs) are foreseen. From preliminary agreement the main links are with the following work packages of the Systems ITD:
- WP3 “Innovative Electrical Wing”
- WP3.2.1 “Innovative Wing System Sub-Assemblies-Technologies development for Regional Aircraft”.

<table>
<thead>
<tr>
<th>Regional IADP WP</th>
<th>Systems ITD WP</th>
<th>Demonstrator (R-IADP or Systems ITD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP 2.3.7 - Enhanced Fuel System &amp; Inerting</td>
<td>WP X - Fuel Systems (tbc upon Core Partner Selection)</td>
<td>System ITD: Fuel Test Facility</td>
</tr>
</tbody>
</table>
## IV. Synthesis of added value with respect to H2020 targets

<table>
<thead>
<tr>
<th>Technology Development</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Completed by</th>
<th>Lead Actors / Key Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive Electric Wing</td>
<td>NLF, Morphing Structure, Advanced HLD, LC&amp;A, Innovative structure, manufacturing &amp; assembly</td>
<td>- 3% CO₂</td>
<td>To maintain the European leadership in regional aircraft design, integration, maintenance and recyclability of new advanced and disruptive systems</td>
<td>Fuel efficiency STOL Reduction of costs of transport (DOC)</td>
<td>2018 (TRL5)</td>
<td>ALENIA, EADS-CASA / Leaders and others (as Core-Partners, CIP-Partners): Universities, Research Institutes, Structural Components Manufacturers; Materials Providers</td>
</tr>
<tr>
<td>Regional Avionics</td>
<td>Advanced Avionic Functions, Innovative Cockpit, Performance and Health Monitoring</td>
<td>- 3% CO₂</td>
<td>To maintain the European leadership in regional aircraft design, integration, maintenance of new advanced systems</td>
<td>Fuel efficiency Noise abatement STOL Reduction of costs of transport (DOC)</td>
<td>2019 (TRL 4)</td>
<td>ALENIA, EADS-CASA / Systems Leaders and others (as Core-Partners, CIP-Partners): Equipment Manufacturers, Universities, SMEs</td>
</tr>
<tr>
<td>Energy Optimized Regional A/C</td>
<td>Advanced EPGDS, E-ECS, Thermal Management, Electrical Landing Gear, Low Power WIPS, Low Noise Propeller, Enhanced Fuel System / Inerting</td>
<td>- 3% CO₂</td>
<td>To maintain the European leadership in regional aircraft design, integration, maintenance of new advanced systems</td>
<td>Fuel efficiency Noise abatement STOL Reduction of costs of transport (DOC)</td>
<td>2018 (TRL 5)</td>
<td>ALENIA, EADS-CASA / Systems Leaders and others (e.g. Equipment Manufacturers, Universities, SMEs, Research Institutes with large test facilities) as Core-Partners or CIP-Partners</td>
</tr>
<tr>
<td>Innovative FCS</td>
<td>Advanced and affordable FCS architecture, Load control and Load Alleviation System, Electro Mechanical Actuation System</td>
<td>- 2% CO₂</td>
<td>To maintain the European leadership in regional aircraft design, integration, maintenance of new advanced systems</td>
<td>Fuel efficiency STOL Reduction of costs of transport (DOC)</td>
<td>2018 (TRL 5)</td>
<td>ALENIA, EADS-CASA / Systems Leaders and others (as Core-Partners, CIP-Partners): Equipment Manufacturers, Universities</td>
</tr>
</tbody>
</table>

Note: All above “Greening Targets” are to be considered with respect to Clean Sky GRA (TP 90 concept a/c for 2020 year) achievements in 2015.
7.5.3 Demonstrations - WP3

The high-level WBS of WP3 demonstration is shown hereafter:

![Figure 7.14 – WP3 Principle Work Breakdown Structure](image)

Currently, to minimize technical and programme risks, for the Flight Demonstration Program, two Flying Test Beds are foreseen (modified existing a/c, TP engine underwing mounted):

- Air vehicle Technologies Demonstrator – Flying Test Bed#1 (FTB1)
- Integrated Technologies Demonstrator – Flying Test Bed#2 (FTB2)

Such flying test beds will be used for demonstration campaigns of:

- Wing structure, aerodynamic, loads alleviation & associated systems performance
- Advanced Flight Controls and General Systems
- Avionics functionalities

In addition, the two flying test beds will be used as environmental survey for technology development regarding cabin passengers/crew comfort and equipment life.

Flying two flight test beds concurrently and simultaneously will minimize risk and development in time for the programme. The total flight test hours remains about the same but at the same time flexibility and risk mitigation are strongly improved. The benefit of using several demonstrators, including the 2 flying test beds is to maximize the possibilities of integrating different technologies into large demonstrators. In the case of the flying test beds the idea is to be able to test in flight the selected technologies.

Having then two flying platforms will increase the capability and minimize the down time for integrating technologies into the flight test activities. As an example different CFRP technologies will be developed in the R-IADP and ITD Airframe for wing. These technologies will be potentially implemented in the flying test beds as they mature sufficiently for flight clearance and testing. For the different technology waves the respective roadmap will show how the technology will be taken to each flying test bed.

The complementarities of the two flight test beds are sought in the technological aspects of:

- **scope**, the technologies applied will focus on the Regional A/C, characteristics specific for the Missions selected; FTB1 (Alenia Aermacchi) will focus on cruise and climb performance while FTB2 (EADS-CASA) will
focus on the Regional A/C operations optimized for short point to point flights, connecting airports with short runways in the middle of a city and pleyade of islands, and advanced high lift performances.

- **approach/Implementation**, the type of solution will be different using a different technology. The technology waves will be managed so that a different solution is implemented (in the cases where this can be done)

For the Ground Demonstration Program, the following ground demonstrators will be built in the R-IADP and will be there used in large laboratory / simulation facilities to validate innovative solutions for future regional aircraft:

- Full Scale Fuselage / Pax Cabin
- Flight Simulator
- Iron Bird

The planning and final results of the activities for the two flight demonstrators will be managed in the Programme Management Committees, where specific part of the agenda will be dedicated to ensure the coordination, interaction, support and cross fertilization.
I. **Air vehicle Technologies Demonstrator - Flying Test Bed #1 (FTB1) - WP3.1**

a. **Demonstration Objectives**

Main objective of this demonstrator is the integration and flight-testing of innovative technologies for a new generation wing and advanced flight control systems. Innovative wing related systems and wing structural solution will also be incorporated as feasible and possible. Aerodynamics enhancements and LC&A features will be demonstrated in-flight, as complement to FTB2, such as: outboard wing featuring laminar airfoils for skin friction reduction; high A/R by means of adaptive/innovative winglets, highly-efficient / low-noise high-lift devices, active loads control system architecture (sensors, control laws, actuators), etc.

Furthermore, this demonstrator will be used to perform in-flight investigation and development of innovative technologies regarding onboard systems, cabin passengers/crew comfort and equipment life. Based upon results of technologies development, a suitable set of requirements for in-flight demonstrations will be produced.

Such requirements will be used to define a well detailed flight test plan and to identify two sets of in-flight test specifications, one for FTB#1 and the other for FTB#2, so to ensure complementarities and synergies between the two flight test beds. A flight test program based on two flying test beds looks more appropriate in order to mitigate the technical/schedule/cost risks associated to the very complex and ambitious demonstration goals and to effectively contribute to the success of the in-flight demonstration programme for regional aircraft.

In particular, for FTB#1 an existing aircraft, turboprop engine underwing mounted, will be selected to be used as Flying Test Bed#1. The choice will reflect the adequacy of the existing aircraft to represent with appropriate modifications the configuration of the innovative airvehicle technologies to be validated. On basis of current assumptions, most of the technologies could be demonstrated by means of appropriate modifications introduced mainly to the outboard part of the wing and in the fuselage.

With this demonstrator the target TRL is 6 for a meaningful set of technologies that will be selected from the following ones, as complement to FTB2, and will be validated in-flight as preliminarily indicated hereafter:

- **AERODYNAMICS**

Natural Laminar Flow Wing: test a/c outboard wing featuring laminar airfoils for skin friction drag reduction.

Winglets: Test a/c wing equipped with innovative (blended, spiroid, split tip type) fixed and/or movable/adaptive winglet for induced drag reduction in climb and cruise flight conditions, and for load control / passive load alleviation.

Low-Noise High-Lift Devices: Test a/c outboard wing with advanced L/E and T/E systems compliant with laminar wings (droop nose, morphing flap) or more innovative/challenging architectures (morphing trailing edge) to reduce airframe noise while preserving high-lift performances. Test a/c outboard wing equipped with conventional passive low-noise solutions (e.g. flap side edge fences) and with innovative T/E “lined” flap conceived as a multi-layer composite structure with micro-perforation on the external surface.

Noise measurements will be performed during the in-flight test demonstration, in order to assess the low noise technologies.

Passive Aerodynamic Solutions: Innovative 3D riblets for turbulent skin friction reduction and innovative coatings for low drag and/or anti-contamination purposes to be applied to both (turbulent region of laminar) wing and fuselage surfaces.
- **LOADS CONTROL & ALLEVIATION**

  Wing Active LC&A: In flight validation of a control system architecture (wing devices, sensors, loads estimators actuators, control laws) for load control (optimized span loads distribution to maximize efficiency in all flight conditions) and load alleviation (to avoid that wing bending and torsion moments from gust and maneuver loads may exceed given limits). In flight validation of performances of conventional / unconventional wing control movables for load control (spanwise segmented T/E devices, mini-tabs, split ailerons, movable winglet) and load alleviation (ailerons symmetrically deflected, adaptive winglet) under wing dynamic response to steady and unsteady conditions.

  Passive Compliant Loads Alleviation: In flight validation of passive "compliant" winglet concept for wing loads alleviation.

  S&C Relaxed Stability with CG management: Investigate handling quality of a more after CoG A/C configuration and design the appropriate Control Law modification to be tested in flight.

- **AEROELASTICS**

  Advanced Vibration Monitoring: In flight concept demonstration and model validation.

  Advanced Dynamic Monitoring: In flight concept demonstration and model validation.

  Cabin Floor Comfort Optimization: In flight comfort model validation and concept demonstration.

- **STRUCTURES**

  Innovative wing design and manufacturing: test a/c outboard composite wing made of advanced materials and manufactured through new production processes (e.g. liquid infusion stiffened panels, advanced process for wing box components manufacturing, high automated process for wing box assembling, ). The wing external shape and sheet refinement will be compliant with demanding requirements of laminar wings in terms of tolerance to surface irregularities (steps/gaps, isolated roughness, waviness). The innovative wing design will include wing self-sensing structure (harvesting sensors, optical fiber, wireless, wires Health Monitoring, humidity detection/control, etc) low life cycle cost methodology, innovative structural test full scale simulation.

- **SYSTEMS**

  Integration within completely new wing architecture of advanced systems, such as Wing Ice Protection System, Advanced Fuel System/Inerting, Actuators for advanced functionalities like morphing aerostructures and load controls/alleviation devices.

- **FLIGHT CONTROL SYSTEM**

  Considering the architecture of the innovative FCS and the basic demo A/C configuration, suitable selections of FCS functionalities/subsystem subset, to be implemented into FTB1, shall be performed; This selection shall keep into account the needs to maintain a good representation of new architecture, to meet budget constraints and not to jeopardizemeaningfully the current A/C certification.

  b. **Added value versus state-of-the-art**

    The most important added value of performing such demonstration in *Clean Sky 2* is the opportunity to integrate in a full operational system (advanced wing) the complete range of technologies that will contribute to create a real breakthrough at system level reaching a true TRL 6.
Normally, in a standard H2020 collaborative research would be near impossible to achieve the same level of integration for such large number of technologies.

c. High level WBS and work sharing

The high level WBS for the Flying Test Bed#1 is shown hereafter:

![High level WBS diagram]

A preliminary work sharing for WP3.1 “Air vehicle Technologies demonstrator” is presented as follows:

- WP3.1.1 activities will be performed by the leading Airframe Manufacturer;
- WP3.1.2, WP3.1.4 activities will be performed by leading Airframe Manufacturer with contributions by other Leaders and Core- or CfP-Partners to be involved in the design and manufacturing of parts/components to be installed on the flight demo aircraft;
- WP3.1.3 activities will be mainly performed by Systems Leaders and other Equipment Manufacturer as Core- or CfP-Partners;
- WP3.1.5 will be performed the leading Airframe Manufacturer and/or Core-Partner

For the Flying Test Bed#1, the main expected contributions from Core-Partners are preliminarily identified as follows:

- Availability of the demo aircraft, modification of the aircraft and flight tests execution
- Design and manufacturing of innovative wing structural parts, eg. Innovative CFRP panels
- Design and manufacturing of equipment
WT Models design and manufacturing
3D WT testing/validation
3D IWT testing/validation
Engineering workpackage(s) for demo aircraft modification design

d. Planning roadmap, targeted technology readiness levels

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<td>1 In-Flight Demonstration Requirements</td>
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<td>3 A/C Modifications Feasibility, Definition and Design</td>
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<td>4 Components / Equipment D&amp;M and Procurement</td>
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<td>5 A/C Modifications Installation and Integration</td>
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<td>6 A/C Ground Tests</td>
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<td>7 Demonstration FTRR (Flight Test Readiness Review)</td>
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<td>8 Demonstration Flight Tests</td>
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<td>9 Flight Test Results Assessment</td>
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Solutions / Equipment from the SYSTEMS ITD

PRELIMINARY SCHEDULE OF INTERACTIONS WITH WP 2 THROUGH WAVES MANAGEMENT:

WV1 - ADAPTIVE ELECTRIC WING (Preliminary TRL Roadmap)

WV 4 - INNOVATIVE FCS (Preliminary TRL Roadmap) (LC&A Actuation, Morphing Actuation)

WV5 - ENERGY OPTIMIZED REGIONAL A/C (Prel. TRL Roadmap) Wing Systems (WIPS, etc.)

WP 2.1 - Active Electric Wing TRL 3

WP 2.4 - Innovative FCS (LC&A + Morphing Actuation) TRL 3

WP 3.4 - Iron Bird TRL 3

WP 2.3 - Energy Optimized Regional A/C Wing Systems (WIPS, etc.) TRL 3

ECD = Estimated Completion Date
Clean Sky 2 Joint Technology Initiative in Aeronautics

e. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

Main interfaces and interactions of the FTB#1 are as follows:

- Interaction with the R-IADP WP2.1 “Wing”
- Interaction with the R-IADP WP2.3 “Energy Optimized Regional Aircraft”
- Interaction with the R-IADP WP2.4 “Innovative FCS”
- Interaction with Systems ITD for regional a/c on-board systems and FCS
- Interaction for some technologies to be developed in the Airframe ITD WP B-4.3 “More Affordable Composite Fuselage”
### f. Synthesis of added value with respect to H2020 targets

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Lead Actors / Key Contributors</th>
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<tbody>
<tr>
<td>Air Vehicle Technologies – Flying Test Bed#1 (FTB1)</td>
<td>Low noise and high efficient HLD, NLF, Active LC&amp;A, Innovative wing structure</td>
<td>+2 / +3% Aerodynamic Efficiency - 4 / -6% Structural Weight - 3 / -5% Fuel Burn - 3 / -5% CO₂ - 1 / -6 EPNdB Ext Noise</td>
<td>Ensure to European Manufacturers technology leadership and concurs to increase of market share by a factor two with consequent jobs creation. Main contributions to technology leadership will be: aerodynamic efficiency, structural weight reduction &amp; functional improvements.</td>
<td>▪ Fuel efficiency ▪ Noise abatement ▪ Reduction of costs of transport (DOC)</td>
<td>2020 (TRL 6)</td>
<td>ALENIA / Leaders and others (Core Partners, CfP Partners): Wing components manufacturers; Research Institutes or Universities with background on WT models/testing; Engineering Organizations</td>
</tr>
</tbody>
</table>

All above green targets are to be considered w.r.t. Clean Sky GRA (TP 90 concept a/c for 2020 year) achievements in 2015.
II. **Fuselage and Pax Cabin Demonstrators - WP3.2**

a. **Demonstration Objectives**

Main objective is the integration and testing of a full scale innovative fuselage and passenger cabin including on board systems and advanced solutions for increasing passenger comfort and safety. The fuselage will be a full scale demonstration of technologies for composite material, structures and manufacturing aimed to weight and cost reduction and to minimize the environmental impact through eco-design and energy consumption optimization all along the life-cycle (towards a zero-impact), integration issues and techniques necessary for realistic product exploitation will be captured. The demo will be integrated with systems such as ECS, Thermal Management, and moreover innovative cabin and interiors will be included together with advanced electrical distribution, heat management, enhanced fire and smoke detection. Cabin will be designed and manufactured in order to demonstrate the new concepts of human based design for improvement of cabin comfort environment.

The integrated Fuselage and Pax Cabin Demonstrations will be made with two main physical items:

1) Long One Piece Fuselage Barrel: this will be the test article that will be used for the demonstrations by structural tests. Starting from the technology level matured in the framework of Clean Sky – GRA ITD and applied to the relevant fuselage barrel demonstrator, the present fuselage on ground demonstration will be addressed to the industrialization feasibility of the fully integrated technologies. In addition to the structure weight minimization objective, the fuselage demonstrator to be realized within Regional IADP will be also aimed to the minimization of manufacturing and assembling costs through the use of high automated processes and to the improvement of ecological impact by means of eco-friendly processes use. As reference only, the diameter dimension of the test article can be foreseen about 3,5 m (TBC). The composite fuselage barrel will include lightning strike capability. It will include also peculiar means to reduce noise/vibration.

The structural demonstration will integrate in a Long One Piece Fuselage Barrel in composite of a Regional A/C. all feasible technologies and methodologies developed within the Airframe ITD for regional a/c, such as:

- Methodologies for modeling & simulation,
- Technologies to improve the environmental impact,
- Hybrid & composite materials,
- Technologies for low cost manufacturing and assembling,
- SMART materials,
- Technologies for complex shapes and high-loaded parts,
- Technologies to improve maintenance.

The design methodologies and technologies to be developed in the above mentioned tasks “Methodologies for modelling & simulation”, “Hybrid & composite materials” and “Technologies to improve maintenance” are also aimed to the assessment of different solutions for repairs considering opportune materials and technologies: 1) temporary and removable solutions, 2) solutions suitable during production, 3) solutions for maintenance. The feasibility study and the respective assessment of these solutions in terms of repair objective, weight and cost saving, repair simplification will contribute to the realization of a working fully automated design methodology for structural sizing which includes also manufacturing, process and assembly constraints.
2) Full scale equipped fuselage barrel (length to be defined): this will be test article that will be used for the pax cabin demonstrations. It will be designed and produced for demonstration and validation of identified comfort objectives and requirements. Safety requirements will be taken in account.

Dedicated ground tests will be carried out to validate the innovative cabin/systems integrated solutions, to verify cabin thermal behavior, validate local and global cabin thermal models and E-ECS pack performances at Cabin environment level, cabin air distribution, humidity and temperature control. Dedicated ground tests will be performed also to demonstrate vibro-acoustic comfort applying external noise sources coming from WP 2.3.6, evaluating noise control treatment optimization and assessing Active noise control systems versus passive ones.

The key technologies, from the Airframe ITD and System ITD that can be addressed on this demonstrator are:

- Innovative multifunctional materials for interiors components (seats, linings and blankets etc.),
- Innovative primary and secondary structure integration concepts,
- New simulation technologies and methodologies for comfort (ergonomics, noise, thermal verification) and maintenance performances demonstrations,
- Innovative production process for structures integrations
- Air quality, including active/passive filtering for improved well being conditions
- Innovative cooling and heat exchange technologies (heat pipes/loop heat pipes, others)
- Exploitation of heat sinks (wall/skin heat exchangers, fuel tank, external flow, etc.)
- Cabin air distribution
- Electrical ECS

Design methodologies will include also investigation to develop design solutions to be validated in cabin demonstrator, to assure easy repair and maintainability of all cabin interiors items without using special tools and minimizing time for repair and maintenance. Lesson learned will be also used. The design approach will also focus in the development of a modular cabin architecture able to be modified and adapted for different customization.

b. Added value versus state-of-the-art

Thanks to the on-ground demonstration of the whole full scale fuselage barrel, an alternative to aluminium alloys will be available for introduction on future regional aircraft. Such demonstration will allow the validation of innovative structural solutions based on composite including all needed functionalities otherwise to be absolved by opportune add-on, increasing costs and weight, and improved rational life cycle cost estimation.

In detail, among the above listed technologies and methodologies to be integrated in the Long One Piece Fuselage Barrel Demonstrator, the development of “Technologies to improve maintenance” and of “SMART materials” are aimed to increase / extend the duration of life of hybrid / composite structures and improve the maintenance protocols in order to lead to reduced operational costs of the aircraft. In particular, the aim is the development of self-monitoring / self-healing composites and inspection / repair technology/methodology, to reduce the time and costs in the service life.

Moreover, peculiar ecological aspects will be improved, in cooperation with ECO transversal activities, thanks to the development of “Technologies to improve the environmental impact” which are aimed to the recovery of the
waste produced during the manufacturing activities and of the End of Life (EoL) composite materials that, otherwise, should be cram in the disposal. The technology will use simple chemical-physical procedures not involving any chemical reactions and needing of low energy consumption. For this reason it leads to a significant improvement of the environmental impact requiring contained costs of production.

With the pax cabin demonstration, very innovative solutions will be demonstrated validating a breakthrough pax cabin design approach which has the human centered in the cabin environment. Capabilities to be validated by this demonstrator will be:

- Multi-disciplinary cabin systems architecture solutions
- Reduced time for installation/removal and repair/maintenance of interiors parts
- Reduced environmental cabin footprint
- Demonstration of weight saving solution at cabin level
- Validation of design solution for cabin global heat exchange coefficient reduction
- Validation of methodologies for cabin ventilation optimisation
- Verification of integration of heat exchange and cooling technologies

Cabin interiors have huge impact on DOC then a particular attention will be applied in choosing and developing the right design solutions in order to assure a high reliability level and service life both at component and system level. Reduction and simplification of the maintainability tasks will be achieved.

The creation of interfaces between high comfort target and cabin architecture is the future challenge when it comes to “intelligent” and modular interior concepts. The challenge is to optimize the comfort aspects but minimize weight still meeting the rules restrictions. The compliance to comfort requirements and achievement of each required performance, also considering the aircraft structural and electrical installation constraints, put the cabin manufacturer into facing the different targets, balancing the several design approaches and finally finding design solutions which usually are not the best for the passenger and flight attendant comfort. These challenges have to be considered, as well as the process of supplier coordination and cost factors. The development of modular cabin architecture will consists of the improvement and optimization of main cabin components: light and comfortable seat, green lining panels, LED lighting system, innovative insulation blanket, lavatory/galleys which highly influence the human requirements for passenger and flight attendant.
c. High level WBS and work sharing

The high-level WBS for the Fuselage / Pax Cabin integrated demonstration is shown hereafter:

A preliminary work-sharing for WP 3.2 Fuselage/Cabin Integrated Demonstration is presented as follows:

- WP3.2.1, WP3.2.5, WP3.2.6 activities will be performed by the leading Airframe Manufacturer;
- WP3.2.2 activities will be performed by leading Airframe Manufacturer with contributions by Core-or CfP-Partners (Software and Hardware Providers for methodologies development, Testing Facilities Providers for structural tests on elements and components);
- WP3.2.3 activities will be also performed by leading Airframe Manufacturer with contributions by Core-or CfP-Partners (Structural Components Manufacturers for peculiar items manufacturing, Manufacturing and Assembling Tools Manufacturers and Provider of High Automated Device for parts manufacturing and final assembly, Aeronautical Materials Providers for the main innovative material providing, SME, etc.);
- WP3.2.4 activities will be mainly performed by the leading Airframe Manufacturer, Systems Leaders, Other Leaders, and other players (e.g. Test Tools Manufacturers for the realization of tools needed to testing phases, Equipment Manufacturer, SME, etc.) as Core- or CfP Partners;
- WP3.2.7 will be performed by the leading Airframe Manufacturer, Cabin Interior, Other Leader, and/or Core-Partners, with Thermal Test facilities (e.g. cabin integrator, cabin interiors supplier/s, cabin system monitoring etc.).
In detail, for the fuselage full-scale demonstrator, the main items expected from Core-Partners are preliminarily identified as follows:

- Customized Software and Hardware for Fuselage, Design and Structural sizing
- Aeronautical Materials
- Manufacturing and Assembling Tools
- High-Automated Devices for manufacturing and assembly.
- Advanced Window frames and Doors
- Fuselage Floor
- OOA Infused Pressure Bulkhead.

For the pax cabin demonstrator, the main items expected from Core-Partners are preliminarily identified as follows:

- Cabin Systems Items and support to testing;
- Ground Test Facility and Test Execution.
d. Planning roadmap, targeted technology readiness levels

**WP 3.2 PRELIMINARY SCHEDULE:**

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<td>10 Final assessment and reports preparation</td>
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<td>Synergy and inputs from Airframe ITD WP B-4.3</td>
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**PRELIMINARY SCHEDULE OF INTERACTIONS WITH AIRFRAME ITD AND WP 2 THROUGH WAVES MANAGEMENT:**

- WV6 - FUSELAGE STRUCTURE (Prel. TRL Roadmap)
- WV7 - PAX CABIN (Prel. TRL Roadmap)
- WV5 - ENERGY OPTIMIZED REGIONAL A/C (Prel. TRL roadmap)
  (E-ECS, Thermal Management, etc.)

- See Airframe ITD: WP B-4.3 More affordable composite fuselage
- See Airframe ITD: WP B-4.4 Low weight, Human Centered Cabin
- WP 2.3 - Energy Optimized Regional Aircraft
  (E-ECS, Thermal Management, etc.)

- TRL 3
- TRL 4

**ECD = Estimated Completion Date**

In accordance with TRL scale definitions previously adopted in the Clean Sky Programme, for WV5 (Energy Optimized Regional Aircraft) this Ground Demonstrator will allow achievement of at least TRL5.

In fact, for systems integration and for the systems technologies, mainly linked to air quality & distribution, thermal management (Cooling/Heating) and Electrical ECS, the development of prototype components, their integration and testing on the Pax Cabin demonstrator will allow technology verification and validation in a relevant environment. During development, as an objective and still in accordance with above TRL scale definitions, it will be evaluated the feasibility to achieve the TRL6 for technology maturity by Verification and Validation of the prototype full compliance to applicable functional, performance, installation and integration requirements in a relevant operational environment.

It will be the case of an high-fidelity sub-system/component prototype built to address all critical scaling issues (form, fit and function) and to operate in a relevant environment, together with feasibility to use the Ground...
Demonstrator to adequately integrate the equipment at system level and validate its operations under critical environmental conditions. As an objective, the test facility will be defined so as to assure the relevant environment requested by TRL6 definition, i.e. testing environment that simulates the key aspects of the operational environment.

e. Interactions with Clean Sky 2 ITDs, IADPs, other interfaces

The activities performed in Clean Sky – GRA ITD – LWC on full-scale fuselage barrel demonstrator will represent a starting link point for developments related to fuselage structure foreseen in the present work package. For the Pax Cabin demonstration, there is no link with the current Clean Sky since there are no activities related to the Pax Cabin of regional a/c.

The activities to be performed in the present work package will be strictly linked with the WP B-4.3 “More Affordable composite fuselage” and WP B-4.4 “Affordable low weight, human centered cabin” of the Airframe ITD. Within the work package is also linked for some technological aspects to WP2.1 “Adaptive Electric Wing”.
f. **Synthesis of added value with respect to H2020 targets**

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Lead Actors / Key Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Scale Innovative Fuselage</td>
<td>Advanced high-toughness materials</td>
<td>- 4 / -6% Structural Weight</td>
<td>Ensure to European Manufacturers technology leadership and</td>
<td>Fuel efficiency</td>
<td>2020 (TRL 6)</td>
<td>ALENIA / Leaders and others (Core Partners, CIP Partners): Materials providers, Structural Components and Tools/Devices</td>
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<td>and Passenger Cabin</td>
<td>Highly integrated structural concepts</td>
<td>- 3 / -5% Fuel Burn</td>
<td>concurs to increase of market share by a factor two with</td>
<td>Reduction of costs of transport (DOC)</td>
<td></td>
<td>Manufacturers, Cabin Systems Manufacturers, Interiors Designers and Manufacturers, Thermal Test Center, Universities,</td>
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<td></td>
<td>SHM for damage detection and condition based maintenance</td>
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<td>consequent jobs creation.</td>
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<td>Research Institutes, Engineering organizations.</td>
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<td>Advanced low-cost manufacturing</td>
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<td>Highly automated assembly</td>
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<td>Human centered cabin design</td>
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<td>All electric/smart systems integration</td>
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All above green targets are to be considered w.r.t. *Clean Sky* GRA (TP 90 concept a/c for 2020 year) achievements in 2015.
III. Flight Simulator – WP3.3

a. Demonstration Objectives

As far as avionic topics are concerned, no validation activities at flight level have been currently planned due to high cost impact on the project as well as due to limitations of the existing regional aircraft that will be used as FTB1. For the time being the validation is at simulation level. Anyway, it has to be considered that for the avionics technologies such validation level is the essential step to be reached prior of their application on aircraft. Starting from the Clean Sky GRA Flight Simulator, an advanced Flight Simulator will be set up and used to demonstrate new cockpit interaction concepts as well as advanced avionics functionalities. During project development the possibility to integrate the Flight Simulator with the Iron Bird will be investigated.

The Clean Sky 2 Regional Flight Simulator will allow the setup of the validation test in a simulation environment representative of regional a/c, enabling the pilot to evaluate new Clean Sky 2 technologies from a functional point of view as well as to evaluate all Human Machine Interface (HMI) issues.

Starting from the Clean Sky GRA Flight Simulator, the evolution towards an advanced CS2 Flight Simulator will be guided by technological studies performed in Clean Sky 2. Main impacts are expected on display, avionics functions and possibly on simulator architecture itself.

Detailed requirements will be defined during the project development, coming from:
- Avionic functions developed in the WP2.2.1 and WP2.2.3;
- Innovative flight deck solution defined in WP2.2.2;
- Customized Extended Cockpit for regional developed and provided by Systems ITD (ref. 11.6.1).

The Customized Extended Cockpit for regional aircraft will be developed in Systems ITD (including technologies for Cockpit Display Systems, Flight Management and Advanced functions (ref. 11.6.1.2)) according to airframer requirements. After development phase the environment will be provided to R-IADP in order to be integrated in Clean Sky 2 Regional Flight Simulator for validation in an environment representative to a regional aircraft.

During project development the objective will be also to integrate the Flight Simulator with the Iron Bird. The aim of this integration is to test, within an operational representative environment (pilot in the loop), the FCS technologies, in order to mature them towards the flight testing activities. However, a gate will be set up in order to take a final decision regarding the physical integration of the two demonstrators.

The purpose of the Clean Sky 2 Regional Flight Simulator is to validate at simulation level Clean Sky 2 technologies; in particular:
- WP2.2.1 - Avionics functions
- WP2.2.2 - Innovative flight deck solutions
- WP2.2.3 - Performance / Health Monitoring
- Technologies received from Systems ITD (integrated in Customized Extended Cockpit for regional aircraft)

The main target benefits are:
- Safety
- Pilot workload reduction
- Pilot Situation awareness improvement
b. **Added value versus state-of-the-art**

The main added value for the Flight Simulator is the possibility to explore innovative solutions taking into account Regional a/c specificities. In fact in Systems ITD only solutions common to all platform (mainly mainline) are demonstrated, while taking advantage of the R-IADP flight simulator it will be possible to take into consideration regional aircraft peculiarities (e.g. space constraints for display, possible limitations for avionics functions w.r.t. mainline aircraft).

The overall idea is that Customized solutions (e.g. avionic functions, display dimensions and format) for regional aircraft applications are received from Systems ITD in order to be integrated in the Flight Simulator for further validation in a regional representative environment, in terms of a/c models (e.g. aeromechanical, engine).

In fact *Clean Sky 2* Regional Flight Simulator will integrate also technologies, impacting a/c performances, from other Technology WPs in R-IADP (e.g. Wing technologies, Innovative Flight Control System).

As far as operational scenarios are concerned, simulation testing activities will be performed considering regional peculiarities (e.g. mission profiles) in a SESAR ATM operational environment (e.g. CPDLC and ADS-C for communications).

As far as the cockpit is concerned, the Cockpit design will be based on a large multi-touch screen technology that will provide flexibility for defining appropriate information presentation. The task sequences and interactions occurring within two-pilot configurations, novelties introduced by SESAR and ALICIA developments will be considered. Such studies, implemented in the Flight Simulator, will allow to assess Human Factor aspects, also taking into account long term technical challenges tied to Single Pilot Operations.

As far as HMI is concerned, the pilot will be requested to evaluate the proposed solution in order to assess the associated pilot workload and situation awareness level. The aim is to verify that, even in flight conditions requiring pilots to manage huge amounts of information, the workload will remain within acceptable human limits and that, despite the expected increased level of automation, the pilot situational awareness will be maintained and enhanced so to assure that the human operator will always be involved and effectively in command.

This topic is important in order to guarantee Safety, which is a really important aspect, considering also Crew Reductions.

The *Clean Sky 2* Regional Flight Simulator will integrate also technologies, impacting a/c performances, from other Technology WPs in R-IADP (e.g. Wing technologies, Innovative Flight Control System).
c. High-level WBS and work-sharing

The high level WBS for the Regional Aircraft Flight Simulator is shown hereafter:

![WP 3.3 Principle Work Breakdown Structure](image)

A preliminary work-sharing for WP3.3 “Flight Simulator” is presented as follows:

- WP3.3.1, WP3.3.2, WP3.3.4, WP3.3.5 activities will be performed by the leading Airframe Manufacturer;
- WP3.3.2, WP3.3.3 will be mainly performed by the leading Airframe Manufacturer, Systems Leaders, and other players (e.g. Equipment Manufacturer, SME, Universities, Engineering Organizations, etc.) as Core- or CfP-Partners. [NH(C)9]

The main items expected from Core-Partners are preliminarily identified as follows:

- Participation to design and development of flight simulator models;
- Equipment Prototypes (hardware/software).
d. Planning roadmap, targeted technology readiness levels

### WP 3.3 PRELIMINARY SCHEDULE:

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**Inputs from the SYSTEMS ITD**

### PRELIMINARY SCHEDULE OF INTERACTIONS WITH WP 2 THROUGH WAVES MANAGEMENT:

- WV 2 - REGIONAL AVIONICS (Preliminary TRL Roadmap)
  - TRL 3 → TRL 4 → TRL 5

- WP 2.2 - Regional Avionics
  - TRL 3
  - TRL 4

ECD = Estimated Completion Date
Main interfaces/interactions are as follows:

- With the Systems ITD: a main interaction is foreseen with the Systems ITD whereby all platform solutions will be pursued, while the R-IADP will address regional a/c specificities. Through this link, all the information related to non-avionics systems, considered in the Systems ITD will be provided to WP2.2 “Regional Avionics”. Preliminary agreements are based on the following interfaces:

<table>
<thead>
<tr>
<th>Note</th>
<th>Regional IADP JTP chapter/ WP</th>
<th>Systems ITD</th>
</tr>
</thead>
<tbody>
<tr>
<td>(*)</td>
<td>Chp.: 7.5.2-II.a WP 2.2.1 - Avionics Functions</td>
<td>WP 1.3 - Flight Management Thales AV</td>
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<tr>
<td>(*)</td>
<td>Chp.: 7.5.2-II.a WP 2.2.1 - Avionics Functions</td>
<td>WP 1.3 - Advanced Functions Thales AV</td>
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<tr>
<td>(*)</td>
<td>Chp.: 7.5.2-II.b WP 2.2.2 - Innovative Flight Deck</td>
<td>WP 1.2 - Cockpit Display Systems Thales AV</td>
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<td>Chp.: 7.5.2-II.c WP 2.2.3 - Maintenance and Health Monitoring</td>
<td>Note: Common interest between R-IADP and Systems ITD (SAFRAN) on Maintenance/ Health Monitoring topic. Once an agreement is found, a link between Systems ITD and R-IADP will be defined</td>
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</table>

As far as (*) activities is concerned, a cross participation with Systems ITD is foreseen and it has been agreed to receive Customized solution for regional application to be integrated in R-IADP Flight Simulator.

- Within the R-IADP: with WP1 “High Efficiency Regional A/C” and WP3.1 “FTB1” (in terms of configuration, performances); as far as Health Monitoring topic is concerned, a main interaction is also foreseen within the R-IADP, because the Flight Simulator will be representative, at adequate level, of non-avionics systems (WP2.3 and WP2.4). For the structural health monitoring, links are foreseen with WP2.1.1.

- With the Airframe ITD: WPB-4.3 for the structural health monitoring.
f. Synthesis of added value with respect to H2020 targets

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Lead Actors / Key contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Simulator</td>
<td>New cockpit interaction concepts, advanced avionics functionalities (including pilot workload reduction), MTM (green functions in a global environment)</td>
<td>-3 / -5% CO₂</td>
<td>Development costs and time-schedule reduction for future regional a/c programs, contributing to European Manufacturers technology leadership and concurs to increase of market share by a factor two with consequent jobs creation.</td>
<td>Contribution to develop a fully integrated ATM/ATC system</td>
<td>2020 (TRL 5)</td>
<td>ALENIA / System Leaders and others (Equipment Manufacturers, SME, Universities), participating as Core Partners or CIP Partners, for flight simulator models development and HW development</td>
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</tbody>
</table>

All above green targets are to be considered w.r.t. Clean Sky GRA (TP 90 concept a/c for 2020 year) achievements in 2015.
IV. **Iron Bird - WP3.4**

a. **Demonstration Objectives**

Virtual and Physical “Iron Birds” will be an important part of the Regional A/C Ground Demonstration Programme. On ground full-scale demonstration as essential step towards the optimization and validation of Regional Aircraft advanced flight control system configuration and interacting aircraft systems incorporating innovative technologies enabling the application of the All/More Electrical Regional Aircraft Concept such as the Electro-mechanical Actuation (for Flight Control and Landing Gear), the Enhanced Electrical Power Distribution and Power/Load Management.

Ground-based engineering tool – named “Iron Bird” integrating, optimizing and validating flight control system and interacting aircraft systems, Electrical, Hydraulic and Landing Gear. It is the physical integration on full-scale infrastructure of these systems, with each laid out in relation to the actual configuration of the aircraft, and all components installed according to the same requirement of the real airframe.

The Iron Bird will also include aircraft model and the simulation of aerodynamic loads on the control surfaces. On the Iron Bird, the main activities that will be conducted are the integration and performance test of Flight Control System and their functional interfaces with Landing Gear System and Electrical Distribution System.

Testing and demonstrations to be performed with the Iron Bird will enable the achievement of TRL 5 for the above advanced systems technologies. In fact this facility has the advantage to test the real test system interfaced with an A/C model and the other simulated systems in a fully representative A/C environment. Testing will be performed both in normal operative condition (fail free configuration) and in degradation/failure condition.

Furthermore, Iron Bird ground testing results will be used to support Verification Process (see ARP-4754 A) in order to achieve the permit-to-fly for the systems modifications that will be implemented on Flying Test Bed 1. The recommended method to reach the above objective are testing and/or analysis, nevertheless due to very integrated and complex demo A/C modification, it is not possible to base this activity only on analysis, so testing by Iron Bird is an essential method.

The main technologies expected to be integrated and demonstrated with the Iron Bird are the following ones:

**Flight Control System**
- Advanced and affordable flight control system architecture for regional A/C
  - Electro mechanical Actuation System
- Load control and Load Alleviation System (sensor, control laws and actuation for new aerodynamic devices)

**Electrical Landing Gear**
- Electrically actuated Extension/Retraction System

**Enhanced Electrical Power Distribution & Load Management**
- Centralized Primary Electrical Power Center with Decentralized secondary distribution modules
- Enhanced Electrical Energy Management (E2-EM) concept with utilization of Solid State based controller (SSPC) and Local ultra/super capacitors (as energy buffer during high transitory energy request)
b. Added value versus state-of-the-art

The Iron Bird will provide a level of development maturity for innovative technologies towards new aircraft such as Regional All Electrical Aircraft that otherwise could only be achieved with more costly and less safe methods. It is the perfect tool to assess the characteristics of advanced systems component and to ground-validate systems architectures and their integration as physical representation of the aircraft. It will enable the detection of incompatibility that may require modifications during early development stages. Additionally, the effects and subsequent treatment of failures introduced in the system can be studied in full detail and recorded for analysis by using the Iron Bird as a test bed.

c. High-level WBS and work-sharing

The high-level WBS for the Regional Aircraft Iron Bird is shown hereafter:

![High-level WBS and work-sharing diagram](image)

Figure 7.18 – WP3.4 Principle Work Breakdown Structure

A preliminary work-sharing for WP3.4 “Iron Bird” is presented as follows:

- WP3.4.1, WP3.4.2, WP3.4.3, WP3.4.4 activities will be performed by the leading Airframe Manufacturer with the involvement of Core-Partners (Equipment Manufacturers, Universities, Research Institutes, SMEs);
WP3.4.5, WP3.4.6 activities will be performed by leading Airframe Manufacturer with support by the above Core-or CFP-Partners.

The main items expected from Core-Partners are preliminarily identified as follows:
- Test Articles Items: Innovative FCS Equipment (hardware/software) and Models; Advanced Electrical Distribution Equipment (hardware/software) and Models;
- Test Benches Items: hardware/software.

d. Planning roadmap, targeted technology readiness levels

<table>
<thead>
<tr>
<th>WP 3.4 PRELIMINARY SCHEDULE:</th>
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<tbody>
<tr>
<td>WP 3.4 Iron Bird</td>
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<tr>
<td>1. Definition of the Iron Bird</td>
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<tr>
<td>2. Design of the Iron Bird</td>
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<tr>
<td>3. Iron bird manufacturing &amp; assembly</td>
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<td>4. Integration of lab equipment / software</td>
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<td>5. Integration of FCS equipment/software</td>
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<td>6. Integration of other systems (EPGDS, E-LGS, ...)</td>
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<td>7. Test to support permit-to-fly</td>
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<td>8. Demonstration</td>
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<td>9. Final Assessment</td>
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<td>10. Demonstration Report</td>
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</tbody>
</table>

Synergy and Inputs from the SYSTEMS ITD

PRELIMINARY SCHEDULE OF INTERACTIONS WITH WP 2 THROUGH WAVES MANAGEMENT:

WP 2.4 - Innovative FCS

WP 2.3 - Energy Optimized Regional A/C

ECD = Estimated Completion Date

This work package has interfaces and interactions with the Systems ITDs. From preliminary agreement the main links are with the following work packages of the Systems ITD:
- WP3 “Innovative Electrical Wing”
- WP3.2.1 “Innovative Wing System Sub-Assemblies-Technologies development for Regional Aircraft”
- WP5.1 “Power Generation”
- WP 5.2 - “Energy Management”

Within the R-IADP it is linked with WP2.1 “Wing”, WP3.1 “FTB#1”, WP3.5 “FTB#2”.

With respect to current Clean Sky, it is linked to GRA WP3 “All Electric Aircraft” and with GRA WP2 “Low Noise Configuration” for the outcomes of activities related to load control/alleviation.
### f. Synthesis of added-value with respect to H2020 targets

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Lead Actors / Key Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Iron Bird</strong></td>
<td>Innovative systems integration, Next generation flight control systems (H/W and pilot in the loop)</td>
<td>The Iron Bird provides an essential contribution to the achievement of in-flight demonstrations for regional a/c, so it contributes to the greening targets of para. 3.3.1.4</td>
<td>Development costs and time-schedule reduction for future regional a/c programs, contributing to European Manufacturers technology leadership and concurs to increase of market share by a factor two with consequent jobs creation.</td>
<td>The Iron Bird contributes to de-risk the introduction of breakthrough technologies for flight controls and electrical systems on future regional a/c which will improve the mobility.</td>
<td>2020 (TRL 5)</td>
<td>ALENIA / Systems Leaders and others (Universities, SME, Equipment Manufacturers, Research Institutes), participating as Core Partners or CIP Partners, for hardware/software development.</td>
</tr>
</tbody>
</table>

All above green targets are to be considered w.r.t. Clean Sky GRA (TP 90 concept a/c for 2020 year) achievements in 2015.
V. Integrated Technologies Demostrator for Turboprop Flying Test Bed #2 (FTB2) – WP3.5

a. Demonstration Objectives

FTB#2 will be conducted ensuring complementarities with FTB#1 as much as possible. In conjunction, both flight tests must provide technical evidences and conclusions in all the aspects associates to the different technologies. From the FTB#2 perspective, the aiming of performing the flight test in two concurrent Flight Test Beds with different demonstrators is manifold:

- The different technologies to test in flight can be distributed in the two FTB in a better alignment with the respective activities of the partners.
- A more rational approach splitting the flight test in two fully concurrent FTB’s allow a more straight forward FTB’s and avoid the constrains in the A/C Demonstrator availability and test plan development.
- In term of cost, the implementation of two FTB’s exhibits a much better solution. The use of a unique Flight Demonstrator would lead to overhead costs and opportunity cost as it constrains the IADP development plan and imposes convergence of all the activities, partners, and technologies into a single Demonstrator, inducing additional risks of the accomplishment of a complete test plan.
- The non-overlapped technologies does not incur in extra cost.
- Different solutions and implementations of similar technologies can be evaluated (eg. Laminar flow at different components) allowing the mitigation of the risks associated to the novel technologies at TRL6.
- For some similar notional technologies, even identical, different goals for the respective FTB#1 and FTB#2 are pursuit.

The particular approach of the FTB#2 is twofold:

- FTB#2 targets a specific advanced Regional A/C concept optimized for short point to point flights, connecting airports with short runways in the middle of a city and pleyade of islands, implying a low cruise speed optimized aircraft with advanced high lift performances based in a Turboprop driven A/C with under wing mounted nacelles whose overall configuration and design are optimized for the entire mission targeting the ACARE goals. The target A/C configuration is aligned to the configuration of the A/C Demonstrator to be employed as departure for the FTB#2.
- The technologies to be demonstrated are implemented and optimized towards that specific A/C concept. The objectives of their evaluation through the FTB#2 are, consequently, in terms of global contribution to the A/C improvement rather than separate technology outcomes. As part of it, the synergies among the different technologies and between the technologies and the A/C design concepts are key aspects to evaluate in the FTB#2.

Complementarily to FTB#1, the technologies tested in FTB#2 will be assessed for certain flight phases (take off, landing, approach, first ascending phase, climb and holdings) mainly targeted by the technologies in FTB#2. This approach for FTB#2 is also present in several activities that in support to this demonstrator will be done in the Airframe ITD.

The top level objectives that have to be assessed through the FTB#2 are the following:

- The advanced integration of novel Power Plant in terms of external and internal architecture of the nacelle and nacelle shapes with new approaches in materials and systems that will lead to minimize the noise in all flight phases, specially the external noise in the ground phases, to reduce the drag and to improve the high lift performances.
Clean Sky 2 Joint Technology Initiative in Aeronautics

- The Optimization (MDO) of the overall wing configuration, taking into account all the disciplines and related technologies in aerodynamics, structure, systems and controls, the Power Plant integration.
- The set of technologies that allows an active optimization of the A/C performances in all the flight phases of the complete mission.
- The high lift conditions for takeoff and landing, ascending and approach operations is one of the main focus in FTB#2 that has to provide evidences about the benefits for the operation in small airports in terms of noise, capabilities for steep descend, or for STOL capabilities, among others and and the quick landing and take-off in hub airports.
- The benefits (in terms of controllability and loads control, etc.) of incorporating low cost customized FBW for the type of regional aircrafts considered in FTB#2.
- The new approaches and technologies in avionics and their synergies with the new cockpit concepts and related technologies, and the requirements towards new objectives (like the single pilot concept) in terms of more autonomous operations and safety improvements.
- The rational approach to energy generation, distribution and handling in combination with the requirements from other innovative concepts for controls, ice protection, ECS, etc. and taking into account the novel PwP concepts.

The implementation of the different technologies and their demonstration in the FTB#2 is pursued for each individual technology. Beyond of that, it is seen essentially from a synergistic point of view, the technologies are evaluated in conjunction among them, providing results and conclusion about their compatibility, their enabling capabilities, and their benefits beyond their isolated use. (e.g.: morphing in combination with laminar flows, composite wing structure with larger aspect ratio wing, etc.).

More detailed objectives and technologies included in the FTB#2 are the following:

- Integration and flight testing of technologies of a new generation regional turbo prop aircraft high lift wing, increase the lift performance of the overall wing at low speed, advanced structural architecture, improved engine integration, advanced nacelle and systems integration and more integrated torsion box manufacturing process with more efficient and advanced materials. In addition, more accurate analysis methods, allowable determination, and certification approach will be validated. This will include the integration and flight testing of a:
  - Wing with advanced Structure concepts.
  - Wing Leading edge Morphing – including actuation by EMAs providing the basis for the integration of anti-ice systems
  - Adaptive winglets morphing - structural devices that might be optimally adapted to different flight conditions through relatively minor shape alteration induced by relative displacement of trailing edge.
  - Structural Health Monitoring systems
  - Adaptive High Performance high lift devices with the inclusion of a new multifunctional flap.
  - Drag reduction including improved laminar flow
  - Active Load protection, including a full usage of wing controls on loads alleviation purpose
  - Improved high wing nacelle and power plant integration, including advanced mounting concepts, and new cowlings, taking advantage of new high temperature resistant materials, and innovative nacelle anti-ice systems
Integration and flight testing of system technologies, this will include:

- Innovative energy harvesting and use of renewable energies
- Use of wireless control, maintenance and health monitoring systems
- High voltage electrical systems
- Electromagnetic hazard protection
- Integrated antennas

Demonstration will be performed using an existing high wing turboprop aircraft, with well determined characteristics, and enough representative of a Regional Aircraft in terms of speed, size, and configuration. This aircraft will be modified to integrate the different structures and systems to be tested. For each of the elements, a flight test plan will be defined and integrated in the flight test plan of the FTB#2.

Flight test plan for the FTB#2 will be coordinated with the FTB#1 in order to optimize the use of resources and reduce and mitigate the risks associated to the ambitious objectives and improve the success of the Regional aircraft flight demonstrations of integrated technologies.

Target TRL is 6 for technologies in the following areas:

- **AERODYNAMICS**
  Natural Laminar Flow
  Aerodynamic flow control for drag reduction
  Flow control technologies applied to delay or mitigate the flow detachments
  Morphing concepts
  Active loads control using combined primary controls
  Aerodynamics and aero-elastic concepts for the passive loads control
  Active loads control using classical primary and innovative controls in combination with functionalities in the FCS
  New nacelle ventilation concepts and nacelle shapes

- **STRUCTURES**
  Innovative wing design and materials, with special emphasis in low cost manufacturing (including the use of thermoplastics and infusion techniques).
  Outer wing skin with spars & stringers manufactured in one-shot process with metallic ribs installation in subsequent assembly
  Optimized of wing attachment fittings for local high load points, flaps, engine mounting, control devices, etc.
  Reduction of the assembly tasks
  Innovative engine mounting concepts, including effects of vibration propagation
  New nacelle materials and constructive concept providing integration of advanced anti-ice system
  High Integration of hybrid components: metallic and composites – system installation optimization from modularity and use of advanced concepts (Optical fiber, wireless, etc). Use of multifunctional materials within new conceptual laminates with improved mechanical, acoustic, electrical, impact resistance and anti-erosion behavior
- **SYSTEMS**

  New systems associated to the engine (fire suppression, anti-ice, etc.)
  Electric actuators for morphing and primary control surfaces
  New structure and systems wireless capabilities both for control, maintenance and health monitoring
  Improvements in wiring leading to reduction of complexity (configuration control, safety) and weight
  Integration of High Voltage electrical systems
  Improved electromagnetic hazard protection
  Integrated antennas

b. **Added value versus state-of-the-art**

  FTB#2 will demonstrate the validity or not of the innovative concepts and technologies in a regional aircraft, with respect to the technologies used in all the regional aircrafts of today, most of them developed in the 80’s
  Validation of those technologies will be made in a joint way, putting most of them together and showing the integration effects, instead of being tested in an independent way
  Technologies demonstrated both for the wing, turboprop nacelle and systems, will be ready to be used in future regional aircraft.

c. **High level WBS and work sharing**

  The high level WBS for the Flying Test Bed#2 is shown hereafter:

  ![Figure 7.19 – WP3.5 Principle Work Breakdown Structure](image-url)
Expected contributions for FTB#2 from Core-Partners are preliminarily identified as follows:

- Design and manufacturing of innovative wing structural parts, eg. morphing wingtip,
- Design and manufacturing of systems or parts of them, e.g. Nacelle anti-ice,
- Design and manufacturing of aircraft testing systems,
- Engineering work packages for demo aircraft modifications.

d. Planning roadmap, targeted technology readiness levels

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<td>WV 3 Cockpit systems (Preliminary TRL Road map)</td>
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<td>WV 2 Adaptive electric wing (Prel. TRL Road map)</td>
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<td>WV 4 Innovative FCS (Preliminary TRL Road map)</td>
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<td>WV 5 Energy optimized Reg A/C (Prel. TRL Road map)</td>
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</table>

Main interfaces and interactions of the FTB#2 are as follows:

- Interaction with all relevant WPs of the Airframe ITD Advanced Turboprop Aircraft
- Interaction with the R-IADP WP2.2 Regional Avionics
- Interaction with the R-IADP WP2.3 Energy Optimized Regional aircraft
- Interaction with the R-IADP WP2.4 Innovative FCS
f. **Synthesis of added value with respect to H2020 targets**

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Lead Actors / Key Contributors</th>
</tr>
</thead>
</table>
| High Lift Advanced Turboprop – Flying Test Bed #2 (FTB2) | Active Wing, Adaptive Aerodynamics, including Morphing Winglets, Systems integration, Advanced CFRP Wing structures, Optimized Powerplant integration | +2 / +3% Aerodynamic Efficiency  
-3 / -5% Structural Weight  
- 2 / -4% Fuel Burn  
- 2 / -4% CO₂  
- 1 / -5 EPNdB Ext Noise | Ensure to European Manufacturers technology leadership and concurs to increase of market share by a factor two with consequent jobs creation. Main contributions to technology leadership will be: aerodynamic efficiency, structural weight reduction & functional improvements. | ▪ Fuel efficiency  
▪ STOL  
▪ Noise reduction  
▪ Reduction of costs of transport (DOC) | Flight Campaign #1: 2017  
Flight Campaign #2: 2018  
Flight Campaign #3: 2020 (TRL 6) | EADS-CASA, Leaders and others (Core Partners, CfP Partners) |

All above green targets are to be considered w.r.t. *Clean Sky GRA (TP 90 concept a/c for 2020 year)* achievements in 2015.
7.5.4 Technologies Development & Demonstration Results - WP4

I. Generalities

The high-level WBS of WP4 is shown hereafter:

![Figure 7.20 – WP4 Principle Work Breakdown Structure](image)

a) Technology Assessment - WP4.1

In this work package the assessment of technologies developed in WP2 and demonstrated in WP3 will be performed.

This WP will interface with the Technology Evaluator, providing inputs for the evaluation of environmental and socio-economic benefits and technology achievements.

In particular, through this work package, the R-IADP will provide the TE with the following main inputs:

- Information about regional a/c technologies and demonstrators development progress
- Information about concept regional aircraft development progress
- Reference Regional Aircraft data and Simulation Model
- Concept Regional Aircraft data and Simulation Models

A preliminary scheme of such interfaces is shown hereafter:
In this work package, the collection of data for technologies developed in WP2 and demonstrated in WP3 will be performed. This work package will interface with the ECO-Design transversal activity and provide the inputs for LCA evaluations.
### 7.5.5 Summary of the R-IADP Plan (TRL, Milestones, Major Deliverables)

A preliminary list of major Milestones / Deliverables of the R-IADP is shown in the following table:

<table>
<thead>
<tr>
<th>Item / Demonstrator</th>
<th>Deliverable</th>
<th>TRL</th>
<th>Expected by</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High-Efficient Next Generation Regional Aircraft Configuration</strong></td>
<td>Aerodynamic and aero-acoustic WTT results for a large-scale complete A/C powered WT model</td>
<td>5</td>
<td>Mid 2020</td>
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<tr>
<td><strong>Ground Demonstrators</strong></td>
<td>Definition of the R-IADP Ground Demonstration Plan</td>
<td>n/a</td>
<td>Beginning 2017</td>
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<tr>
<td><strong>Flight Demonstrators</strong></td>
<td>Definition of the R-IADP Flight Demonstration Plan</td>
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<td>Beginning 2017</td>
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<tr>
<td><strong>Flying Test Bed#1 (FTB1)</strong></td>
<td>Final Selection of the FTB1 A/C</td>
<td>n/a</td>
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<td></td>
<td>Availability of FTB1 demo aircraft</td>
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<td>Mid 2020</td>
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<td>FTB1 Flight Test Results</td>
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<td>Mid 2021</td>
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<tr>
<td><strong>Flying Test Bed#2 (FTB2)</strong></td>
<td>Final Selection of the FTB2 A/C</td>
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<td>Availability of FTB2 demo aircraft</td>
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<td>FTB2 Flight Test Results – 1st Flight Test Campaign (Systems)</td>
<td>6</td>
<td>2018</td>
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<tr>
<td></td>
<td>FTB2 Flight Test Results – 2nd Flight Test Campaign (Wing &amp; Systems)</td>
<td>6</td>
<td>2020</td>
</tr>
<tr>
<td><strong>Fuselage and Pax Cabin</strong></td>
<td>Full scale fuselage demo definition</td>
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<td>Beginning 2017</td>
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<td></td>
<td>Full Scale Fuselage Design</td>
<td>5</td>
<td>Mid 2018</td>
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<tr>
<td></td>
<td>Full scale fuselage structural test</td>
<td>6</td>
<td>Mid 2021</td>
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<td>Pax Cabin Demonstration Tests</td>
<td>6</td>
<td>Mid 2021</td>
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<td><strong>Iron Bird</strong></td>
<td>Iron Bird Design</td>
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<td></td>
<td>Iron Bird Test Readiness Review</td>
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<td>Mid 2019</td>
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<td>Iron Bird Demonstration Tests</td>
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<td>End 2020</td>
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<td><strong>Flight Simulator</strong></td>
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<td>Flight Simulator Demo (Spiral #1)</td>
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<td>End 2017</td>
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<tr>
<td></td>
<td>Flight Simulator Demo (Spiral #2)</td>
<td>5</td>
<td>Mid 2020</td>
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*n/a = not applicable*
8 Fast Rotorcraft IADP

8.1 Going beyond Clean Sky

In the frame of Clean Sky, research activities were focused on several areas covering main and tail rotors, active systems for main rotor blades, drag reduction for airframe and non-lifting systems, electrical systems, eco-friendly flight paths and eco-friendly life cycle processes.

Among all technologies developed, the following ones are believed to be worthy of exploitation also for the benefits of Clean Sky 2, in particular:

- Rotor blade 3D tailoring for higher energy efficiency and reduced acoustic emission, reaching TRL 5 with full scale realization of a blade set and performance test at the whirl tower;
- Methodologies for aerodynamic optimization (drag reduction) reaching TRL4 and turbo-shaft installation reaching TRL6;
- Electrical technologies on selected components concerning power conversion, energy storage and distribution reaching TRL5;
- Methodologies to predict optimal flight paths to minimize noise and pollutant emissions, tested through flight simulator, including pilot-in-the-loop, and verified in flight (helicopters, not tiltrotors) reaching TRL6;
- Use of thermoplastic material for structural components, based on what experienced in designing, manufacturing and testing a tail cone demonstrator reaching TRL5;
- Use of new green coating processing for metallic parts (aluminum, magnesium, steel), reaching TRL5.

Whilst most Clean Sky projects just reached their mid-life by end 2012 with critical design reviews successfully passed, the list above indicates which level of maturity will be achieved when research activities covering 2013-2016 period will be completed. In general terms, Clean Sky GRC is developing a range of individual technologies covering mainly conventional helicopters and is not addressing high level of integration at system level and extensively cleared for flight even though some of them will be on board of flying test beds when and if tests in “relevant environment” are to be carried out. The subsequent integration steps are what Clean Sky 2 will cater for, integrating the results of Clean Sky GRC with those of earlier programs (Friendcopter, ERICA, Nicetrip) in a comprehensive full vehicle design approach to be pursued up to large scale flight demonstrations of novel rotorcraft configurations. Furthermore, in addition to environmental challenges that must be dealt with in short and long term future, other topics need to be addressed, as they are stated in Horizon 2020 call for a ‘Smart, Green and Integrated Transport’, namely industrial leadership and new mobility concept. A long-term commitment, strategic-results driven, focused instrument like Clean Sky 2 will provide the necessary environment within which R&T and innovation can develop the enablers to respond to such challenges. It is also expected that Clean Sky 2 focus on fast rotorcraft will permit to develop research innovation activities which will benefit to conventional helicopters as well, thus providing a wide positive effect in rotary-wing technologies as a whole.
8.2 Challenges to be tackled for Fast Rotorcraft in the Horizon 2020 Period

Until today, helicopters form the essential part of Vertical Take-Off and Landing (VTOL) aircraft inventories; other VTOL configurations are limited to a few military vehicles: vectored-thrust fighters (Harrier AV-8B; F35B still in development) and the V22 tiltrotor aircraft. In addition, the AW609 tiltrotor aircraft is currently under development and certification process both in both USA and Europe. Compound rotorcraft vehicles featuring a helicopter-like lifting rotor with additional wings and propeller(s) have been recently developed and successfully experimented both in USA and in Europe as technology demonstrators.

The European rotorcraft industry has reached a predominant position in the helicopter global market and can be stated as a world leader in the civil sector with more than 50% of sales in a market which is steadily growing in spite of the current global economic downturn (growth rate >5% per year, civil market average over the last ten years).

Pursuing excellence in technology and investing in innovation have been key factors to favour this success. EU manufacturers’ innovative products could be developed thanks to a considerable technology portfolio built and strengthened thanks to ambitious research projects supported by own investments, national programmes and EU framework programmes. Research activities carried out within EU programs have contributed to noise impact reduction and aerodynamic performance of conventional helicopter. The consolidation of EU helicopter manufacturers into two large transnational groups (each of them now incorporating three different national entities) lead them to increasingly rely on R&T programmes organised at EU level and in particular to commit in a comprehensive package of activities conducted with research associates and partners as part of the Clean Sky JTI (CS).

A severe global competition, growing and changing demand in the rotorcraft sector is facing new challenges. New competitors are rising in particular among the emerging countries. These new entrants as well as other non-EU countries that were already global competitors, keep sustaining their innovation with massive national funding mainly from defence budget but aiming at products targeting also the civil sector. The world and the EU society have changed since Vision 2020 for aeronautics was issued and Clean Sky JTI was established. Today the global demand within and outside EU for a smart air mobility and transport system (i.e., more flexible, resilient, effective, affordable) has increased and it is expected to further grow in the future. Increasing request for rotorcraft transport exists today in spite of the global economic downturn. The Flightpath 2050 mobility objective of 90% of door-to-door trips within Europe to be completed in less than 4 hours, captures a deep-rooted and permanent social aspiration which is confirmed also for rotorcraft.

Beside the quest for mobility, a strongly growing demand is also observed and expected to accelerate for multiple airborne services addressing life protection, and citizens’ safety, such as search & rescue, emergency medical service, civil security, disaster relief, etc.

A few statistical figures for average yearly market growth in a ten year period (worldwide, 2000-2010) can clearly illustrate the trends: commercial passenger transport: +16%; EMS: +11%; maritime SAR: +25%. Two examples showing the vital character of some helicopter services that help understanding the fast growing demand:

- In Germany alone\textsuperscript{11}, the 60,000 missions flown each year save at least 5,000 lives;

\textsuperscript{11} European HEMS and Air Rescue Committee.
During the Katrina hurricane in Louisiana (2005), more than 350 helicopters were involved at the height of relief efforts. “Search and rescue operations alone saved 24,135 lives from imminent danger, usually off the roofs of the victims’ homes as flood waters lapped at their feet”

This growth in demand goes in parallel with the requirement to guarantee the sufficient environmental compatibility (considering also the expected traffic increase) and stay on track along the roadmap for a clean aviation stated by Flightpath 2050 and ACARE.

That broad and growing variety of utility and transport missions represents a true asset for helicopters and rotorcraft in general. The full potential of the market will of course become evident with the introduction of the first new configurations. It appears however obvious from the past records, that performance improvements made possible by technological progress and innovative configurations (e.g. the Fenestron® shrouded tail rotor, bearingless and elastomeric rotor hubs, advanced cockpit with synthetic vision systems), are instrumental to respond the market needs and secure the good position of EU industry.

Today, the EU technology portfolio which may be tapped to satisfy the needs for VTOL transport and public services contains a number of individually matured systems and technologies, many of them emerging through the current Clean Sky JTI. They are primarily designed for integration on conventional helicopters but most of them would be applicable to Fast Rotorcraft concepts as well, possibly with some adaptation. In the technology portfolio, the knowledge regarding non-conventional fast rotorcraft configurations, namely the tiltrotor aircraft and the compound rotorcraft, was acquired recently by EU industry through dedicated studies and limited experimental flights.

The rotorcraft global market forecast studies [TF13] indicate that the average growth rate of 4 to 5% per annum observed for conventional helicopters will persist in the next ten years, mainly to satisfy the demand in North America and in emerging countries. In several segments such as passenger transport, emergency, search and rescue, the additional demand for higher speed and longer range VTOL aircraft with the associated fuel savings made possible thanks to inherently good aerodynamic characteristics of new rotorcraft configurations is estimated to reach at least one thousand units over a period of ten years after their market entry foreseen in the 2020 to 2025 timeframe [AT14].

Research and Innovation Scenario for Rotorcraft

Rotorcraft research and innovation activities are well inserted in the wider domain of R&I of aeronautics and flight operations, together with fixed-wing platforms and services. However, rotorcraft technologies and operations are, respectively, characterised by high level of integration and complexity from one side and a plethora of diversified type of operations (transport, search and rescue, disaster relief, etc.). Industries and stakeholders that are involved in rotorcraft technologies must face with many and diversified challenges. Research programs topics need therefore to be linked to airworthiness and safety, architectures and technologies economically affordable and profitable both for industry and customers, as well as effective solutions to be proven in service. These considerations bring to an approach in which R&I subjects in rotorcraft domain move from a conventional “platform-centred” type of activities to a “service-centred” area, where ‘service’ here must be intended as what the end user obtains as a combination of rotorcraft platform architecture, its technologies and systems, the operational and MRO capability, economic affordability, social implications.

The picture depicted above generally drives the R&I activities selection process for rotorcraft. These topics can however be matched today by promising technological progress in various fields of science and engineering. Some of these are intrinsic to aeronautics (aerodynamics/aeroacoustics, system integration of
complex systems, man-machine interface, simulation, etc.), while others stem from other branches and are more transversal (advanced materials and electronics, sensors, data management, eco-friendly technologies and systems, etc.).

The combination of these two main innovation drivers has brought today to Fast Rotorcraft research projects: they will include the activities that will develop and prove the feasibility of advanced architecture and they will count on insertion of various enabling technologies to address optimal performance and operational flexibility, in a safe, economically viable, and more environmentally compatible manner.

8.3 The Role of the Fast Rotorcraft Projects

The European Rotorcraft currently enjoys a predominant position on the global, civil helicopter market mainly due to technical excellence resulting from past investments in research and technology development.

Over the last decades EU industry invested own research funds in order to acquire the basic engineering know-how about fast rotorcraft configurations. These are rotary-wing platforms capable of reaching forward flight speed of 200-300 knots and above, while maintaining good hover capabilities, in basically two types of configuration: the tiltrotor aircraft and the compound aircraft. Both configurations are aimed at responding to demanding operational requirements which cannot be satisfactorily met with conventional helicopter architectures, but also to new demands that are emerging from current and possible new markets. Times are now mature to make a decisive step ahead in the research and validation of fast rotorcraft platform along with EU aviation research initiatives.

Several non-EU competitors are well prepared as extensive demonstrations and product developments already took place with massive public support for military programs, and civil products are expected to be developed on short terms.

Fast rotorcraft platforms are currently flying within and outside Europe, a clear demonstration that this type of aircraft is not restricted to X-planes or small UAVs. Nonetheless, there still are a number of milestones that need to be accomplished in to mature fast rotorcraft and to firmly establish them as an intermediate solution in the middle of an ‘aviation continuum’ spanning from conventional relatively low speed helicopters to medium and large fast airplanes:

- Fast rotorcraft architectures are new and their level of complexity is greater than conventional and well known helicopters;
- Being new, fast rotorcraft must still evolve to meet operators’ demand for a technically efficient and safe and economically affordable platform;
- Fast rotorcraft has not been certified yet in civil sector and certification standards are not firmly established yet.

Several benefits and technological fallouts are expected from fast rotorcraft projects:

- Technical solutions developed in Clean Sky to reduce the emissions will be applied in the design of these new demonstrators aiming to prove the concepts’ potential operational effectiveness at vehicle level and in the European transport system. Environmental compatibility targets aligned with the current ACARE 2020 agenda and foreseeing the longer term Flightpath 2050 objectives will be pursued by combining technology research in areas of platform efficiency (emissions, life cycle environmental impact, etc.).
Sustaining the R&T and demonstration activities (structures, materials, aerodynamics, aeroacoustics, aeroelasticity, electrical systems, sensors, system integration, processes, operational concepts, etc.) will permit to mobilize a wider EU supply chain beyond the six countries where the two OEM integrators have their design and research facilities, to be complemented by other partners across EU (as happening in current Clean Sky, where 16 countries are involved in Green Rotorcraft ITD). R&T demonstration and validation will be the main answer to develop the enablers and the solutions that will allow establishing a clear roadmap to make fast rotorcraft successful.

Fast Rotorcraft platforms will provide more speed, longer range, more productivity (combination of payload x speed referred to cost of ownership and operation) to fill the gap between conventional helicopters and other fixed-wing platforms (see chart).

Fast Rotorcraft platforms will demonstrate how these configurations will provide new and more efficient and effective services to citizens while matching the needs and requirements of operators. In doing so, they will benefit from ground infrastructures, such as a network of helipad and airports and with associated services while integrating in the new Air Traffic Management requirements, at the same time providing with their flexibility a further degree of freedom to ATS in general. This will enable delivering services through a type of air transport with unprecedented characteristics: rescuing and helping injured people faster and further; extending mission capability and flexibility in disaster relief missions; covering very demanding requirements for transportation to oil & gas platforms, to enable more effective access to natural resources; complementing current and future air transport of passengers and freight with a new “grid” providing the potential to exploit new concepts of inter-modality.

With high maturity of technology integration aimed at completion of this rotorcraft program including flight demonstrations, the possibility to match ACARE goals (sustainable mobility) with actual products to be subsequently developed will be substantiated. Meeting a TRL6 maturity level for the whole rotorcraft
Clean Sky 2 Joint Technology Initiative in Aeronautics

system indeed means that each of the flight demonstrators will embody a consistent overall aircraft concept with its components design and sized to match definite operational specifications and that the test program will allow assessing the compliance or deviations with respect to these specifications. Even though the demonstrators will not have to pass certification criteria and the serialization process will not be implemented, the potential showstoppers for a subsequent product development and marketing will be identified, analysed and circumvented with appropriate mitigation measures.

After Clean Sky 2 completion, the actual performance achievements including the industrial and economical aspects will be analysed in front of the various market needs and of foreign competitors’ offers; the strategy to develop products implementing the high speed configurations will then be derived which may require some further adaptation in terms of vehicle size, capacity, range of operational capabilities.

The high speed configurations will also integrate results of technology developments performed outside of Clean Sky2 (additional activities) whose needs may be revealed during the early design phase of the demonstrators and considered essential to meet the market objectives.

It is well understood that the level of ambition in this demonstration program entails substantial risks that its objectives might ultimately be achieved only partially and that the market demand and societal challenges might be incompletely met. However this program will be monitored continuously during its course with many opportunities to adapt or re-orient it in case unforeseen obstacles would threaten its realization in some crucial aspects. Many technologies developed in this endeavour e.g. weight-optimized fuselage, drive system, efficient on-board power management have a broad range of potential applications beyond high speed rotorcraft and could be implemented for helicopters, turboprop aircraft or general aviation with limited additional effort.
8.4 Fast Rotorcraft IADP General Organisation

The fast Rotorcraft IADP is structured in three upper level work packages:

- WP0 in which all transverse activities that form the common stem for the two demonstration projects, including consortium management;
- WP1 includes all activities specific to the Next Generation Civil Tiltrotor demonstration;
- WP2 includes all activities specific to the Compound Rotorcraft demonstration.

8.5 Management & Transversal Activities – WP0

The transversal activities that are performed jointly by the leaders and core partners and some of the partners include the following work packages and as illustrated on the diagram here below.

- WP0.0 Consortium management activities required to monitor and steer the IADP in liaison with the JU officers;
- WP0.1 Technology Evaluator methodology and tools;
- WP0.2 Eco Design concept implementation.

Because of the substantial differences in vehicle and system architecture, operation and technologies, it is not foreseen that a significant amount of synergy will be possible for certification, however a joint consultation team will be established to progressively identify opportunities concerning operational aspects.
8.5.1 WP 0.1 [TF21] Consortium Management

- **Relevance and objective**

The non-technical activities WP0.1 are required to ensure effective monitoring of technical activities in liaison with the JU and the other project within the IADP Rotorcraft throughout the whole duration of the project.

This will ensure the timely achievement of high quality technical demonstrations, and at providing proficient contractual and budgetary support and coordination of the projects. It also intends to ensure that knowledge management and other innovation-related activities are coordinated at IADP level as appropriate.

- **Management Principles**

The IADP management, coordination and decisions are handled by the Consortium Bodies, respectively:

- the Consortium Coordinator,
- the Project Management Committees,
- the Steering Committee.

The Steering Committee is the main decision and governing body of the IADP. It is chaired alternatively by representatives of AgustaWestland and Airbus Helicopters groups. Progress and financial reports, implementation plans and reports, work packages for Partners are prepared and submitted for decision to the Steering Committee by the Project Management Committees. Each Project Management Committee headed by a Project Leader is in charge of the timely implementation of orientations and decisions relevant to its work scope as taken by the Steering Committee and performs the corresponding administrative tasks. Each Project Management Committee is supported by the Subproject Team Leaders; each of them deploys management activities at technical and coordination level within the scope of each specific technical subproject.

These management principles and the application rules will comply with and complement the Clean Sky general rules and procedures, and with the terms of the IADP Grant Agreement (to be concluded prior activity start). They will be further detailed in the IADP Consortium Agreement.

An IADP Management and Quality Plan will be established to define the roles and responsibilities of individuals contributors. It will implement and cascade the provisions of the JU Management Plan.

The WP0.1 organization will be based on that already implemented in Clean Sky GRC (WP GRC0) taking due account of lessons learnt and of the necessary adaptation needed to meet the objectives of the new demonstrations. As far as possible and relevant, management meetings of Clean Sky GRC and Clean Sky 2 Fast Rotorcraft IADP will be coordinated in order to ensure a smooth transition and the transfer of information between the two related programmes.

- **Activity overview**

The following tasks will be performed in WP0.1:

- Establishment and regular revision of the work plan (objectives, schedule, deliverables, budget, topics for calls) that lead to Grant Agreement amendments or change requests;
- Technical and financial reporting (progress, Key Performance Indicators, resource and budget consumptions, deviations w.r.t. plan, risks);
- Establishment and up keeping of IADP specific management tools and templates (rules of procedures, IT shared repository, IADP specific agreements and cross-agreements with the ITDs);
- Management of IADP results (document registers, dissemination register, TRL review register, mutually granted access rights, etc)
The Consortium Coordinator will be nominated alternatively from AgustaWestland and from Airbus Helicopters groups. He/she drives the WP0.1 and will be the main contributor. Other contributors are the other Leaders and Core Partners involved in the IADP as Project Management Committees or high level technical Work Package leaders.

This WP is subdivided in five low level work packages and includes contractual non-technical management tasks performed at JU and IADP levels. Its organization is based on experience and lessons learnt from the Clean Sky GRC ITD; a seamless and easy transition from Clean Sky is therefore expected. Most tasks will run continuously throughout the project duration; except for WP0.1.4 devoted to Management Plan and Tools which will be more concentrated in the first nine months and then have a limited activity devoted to updates and corrections. On the other hand, WP 0.1.5 devoted to Management of Progress & Results will become really active when methods and tools are firmly established and first evidence of progress appears i.e. after that early period. WP0.1.5 will handle progress and TRL monitoring, risk management and mitigation, dissemination and exploitation plans at overall Fast Rotorcraft IADP level under management committee supervision; these activities will also cascade in the work packages under WP leaders’ supervision.

I. High-Level WBS

Figure 8.3 High level WBS
8.5.2 WP 0.2 [TF23] Technology Evaluator methodology for fast rotorcraft

- Relevance and objective

This work package aims to provide a common coordination of Technology Evaluator related activities for the Fast Rotorcraft IADP of potential shared areas between the two projects of Tiltrotor and Compound platforms. This work package will also provide the common interface with the Technology Evaluator and relevant participants for effective assessment of fast rotorcraft progress towards Clean Sky 2 goals.

- Activity overview

The IADP Leaders and the TE participants will jointly define SMART objectives and criteria adapted to the fast rotorcraft missions in line with the general TE approach for Clean Sky 2. Possible relevant common tools used in Clean Sky GRC will be adapted and further developed in order to enable the assessment of conceptual rotorcraft models corresponding to the new configurations to be demonstrated. Possible suitable common baselines and reference fleets will be explored as well as scenarios for future fleets. Potential domains for assessment in collaboration with the TE could include the environmental, competiveness, productivity and smart mobility domains.

8.5.3 WP 0.3 Eco-Design concept implementation to fast rotorcraft

- Relevance and objective

This work package aims at ensuring the coordination of Eco-Design relevant activities performed in the two rotorcraft demonstration projects and also other platforms in the Clean Sky 2 programme. Eco-Design relevant activities mean those related with to new design and production techniques along the supply chain that can contribute minimizing the environmental impact of aeronautical products throughout their whole life cycle, including production, operation, maintenance, repair and dismantling or recycling. This work package belongs to the Eco-Design Transverse Area and builds upon the methods and results delivered by work packages EDA and EDS in Clean Sky but with a decentralised organisation.

The WP0.3 participants are the FR-IADP Leaders, the Fraunhofer Institutes, and the Core Partners and Partners concerned with production, maintenance and end of life management of rotorcraft products. The capability to contribute to the Eco-Design approach and collaborate with the FRC-IADP Consortium is part of the competence mix expected from the candidate Core Partners and Partners for the relevant work packages.

The cardinal objective is to synthesise the benefits of new Eco-Design techniques such as materials, production processes, maintenance, dismantling and recycling developed and implemented across Clean Sky GRC, FR-IDAP and rotorcraft-related WPs in Airframe ITD.

- Activity overview

The Life Cycle assessment methods and tools will be further implemented following their development in the Clean Sky.

The environmental and benefits will be up-scaled at whole rotorcraft level based on bills of materials, and life cycle data (including weight deltas) and life cycle assessments acquired as part of technology developments performed for the rotorcraft demonstrators (FR-IADP WPs 1.3, 2 - 1.4 – 2.1.5 – 2.2 – 2.5.5) and at a more generic level within the Airframe ITD (AIR-ITD WPs A1.5 - B1.1 - B3.4 –B4.1 – B4.2).
8.6 Next Generation Civil Tiltrotor (NextGenCTR) Project – WP1

8.6.1 Scope of the Project

The next generation civil tiltrotor project (NextGenCTR) will be aimed at designing, building and flying a technology demonstrator to validate an innovative tiltrotor concept, the configuration of which will go beyond current architectures of this type of aircraft. NextGenCTR’s demonstration activities will aim at validating the architecture, technologies, systems and operational concepts of this rotorcraft, to demonstrate significant improvements with respect the current state-of-the-art for tiltrotors. The project will also allow developing substantial R&T activities to increase the know-how about tiltrotors and to generate steady, high volume research and innovation activities comparable to that of well proven helicopter platforms. The project will therefore sow the seeds of further research and innovation opportunities for the period post-2020 to sustain the development of technologies for products targeting 2030 entry into service date.

8.6.2 Tiltrotors: the Concept and Historical Background about Industrial and Research Programmes

Tiltrotors combine features of helicopters and fixed-wing aircraft. They are capable of vertical takeoff and landing like conventional helicopters, while can reach speeds in forward flight above 300 knots (550-600 km/h) typical of fixed-wing aircraft and outside of the capabilities of helicopters. This operational flexibility is provided by tilting the rotor axis, which is vertical during vertical take-off and landing (helicopter mode), or horizontal when flying forward at high velocity (airplane mode).

The first idea of tiltrotor dates back to 1930 when concepts were born in which propellers were allowed to rotate from vertical to horizontal, with aircraft taking off and landing vertically. At the end of the 40s, with the emergence of civil aeronautics and the development of the helicopter, the idea of creating an aircraft able to merge the advantages of the helicopter and propeller-driven airplane began to take shape. However, lack of knowledge and technological limitations, combined with greater complexity and high cost related to a development of a tiltrotor, slowed the research in this direction.

The first aircraft capable of carrying out a transition from helicopter mode to airplane mode was designed and built in 1954: the Transcendental Model 1-G.

It was the Bell XV-3, which flew until 1966, which first demonstrated the solid characteristics of the tiltrotor concept and gathered valuable data necessary for technical improvements in future projects. In 1972 Bell Helicopter Textron started the development of the XV-15, a twin-engine tiltrotor research aircraft. Two prototypes were built to demonstrate the tiltrotor concept and explore the operating flight envelope for military and civil applications. With these successful prototypes, the operating potential, ease of piloting, and passenger comfort were demonstrated.
The success of XV-15 helped launching the V-22 Osprey defence program in 1981 in the United States. Through industrial collaboration programs, this tiltrotor flew in 1988 for the first time. V-22 has achieved military qualification and it operates within the Air Force and Navy of the United States of America.

The V-22 is the result of a long series of attempts to create a tiltrotor that could combine the advantages of the helicopter and turboprop, reducing their limitations: low speed horizontal flight and limited maximum operating height for the helicopter and inability of the turboprop to take off and land in confined spaces. Today, the V-22 Osprey operates in a number of missions in the defence sector.

Following in the footsteps of the V-22 Osprey, given the direct involvement of Bell, the Bell-Boeing 609, a medium light tiltrotor (7 tons class) for civilian use, was launched in 1996: the first prototype made its maiden flight in 2003. In 1998 Boeing left the program and AgustaWestland stepped in. In June 2011, AgustaWestland took full ownership of the program and renamed the project AW609.

The AW609 is an aircraft for civil short and medium range missions and applications. Its configuration includes two nacelles in which the engines and rotors are installed, located on the wing tips. These nacelles have the ability to rotate for slightly over 90 degrees between the vertical position (for takeoff/vertical landing) and the horizontal (for the forward flight at medium and high speeds). This versatility allows the AW609 to fly at a speed close to twice that of a typical helicopter.
In parallel to the development and production of the AW609, the project ERICA (Enhanced Rotorcraft Innovative Concept Achievement) was launched in Europe and funded by European Commission in the frame of research and innovation Framework Programme 5. ERICA is a project aiming to develop innovative solutions to overcome some aspects of the current configuration of the tiltrotor that limit its efficiency in hover and cruise conditions. This project was coordinated by AgustaWestland with the contribution of major European industries, research centres and universities and proposed five projects for basic research and technological development at the system or sub-system level. After the completion of ERICA AgustaWestland, together with other European partners, launched the project NICETRIP (Novel Innovative Competitive Effective Tiltrotor Integrated Project), a new phase of maturation of the tiltrotor technology, to integrate the results of research carried out in ERICA. NICETRIP is funded by European Commission through Framework Programme 6. A distinguishing element of the vehicle architecture studied under ERICA and NICETRIP projects compared to the current state of the art represented by the AW609 configuration is the ability to rotate the outer part of the wing subject to rotor downwash in hover flight in order to reduce flow impingement and consequent lift loss. The outer wing rotates independently of the nacelle to convert back to horizontal as soon as forward flight is initiated to minimise drag during conversion. This solution improves the aerodynamic efficiency of the rotor in hovering conditions, while allowing the use of a smaller rotor for a given vehicle weight. This allows to achieve higher propulsive efficiency in forward flight.
8.6.3 Legacy with Clean Sky

NextGenCTR will continue and further develop what has been initiated in Clean Sky (which is very much related to conventional helicopters), and will launch new activities specific to Clean Sky 2 and NextGenCTR project. In the area of CO₂ emissions reduction, NextGenCTR will continue the development of engine installation and flight trajectories optimisation. These research themes are being pursued under the current Clean Sky program through analytical models and with scaled model tests, whereas Clean Sky 2 will validate the results at full scale. Specific Clean Sky 2 new activities on drag reduction of prop-rotors, fuselage and wing will be necessary due to new generation of prop-rotors, modified fuselage-wing architecture and to achieve the increased efficiency to match the EU roadmap for CO₂ emissions reduction. This latter Clean Sky 2 specific topic will reduce operating costs, improving competitiveness of the architecture and solutions adopted. Prop-rotor development to reduce noise emissions will require substantial aeroacoustic research through modelling, tests and full-scale validation. Under current Clean Sky, noise reduction is mainly addressed through flight trajectory optimisation. This technological research stream will continue in Clean Sky 2 and will be linked to SESAR concepts where worthwhile. Clean Sky 2 transversal subjects will cover new materials, such as thermoplastic matrix composites, surface treatments, less hydraulics and more electrical systems, while validating them at full scale and in real operational conditions, simultaneously sustaining the development of Technology Evaluator for the case of tiltrotor and rotorcraft in general.
The following time line shows the phasing of Clean Sky GRC and other EU research programs with Clean Sky 2 activities:
Activities that are in current Clean Sky GRC and are eligible to be continued in Clean Sky 2:

- A part of Clean Sky Green Rotorcraft project is focused on common tiltrotor (based on ERICA project) in the area of fuselage shape and engine installation drag optimization. The core of these activities has been the development of an aerodynamic optimization algorithm which will be validated through wind tunnel tests of a scaled model of ERICA. The development of this tool will contribute to optimal aerodynamic design of tiltrotors, including critical details like wing-fuselage interface, nacelles and engine installation. This activity will be further developed in Clean Sky 2 since the final design will be chosen in NextGenCTR to achieve the challenging improved drag efficiency objectives and validation in flight will then be carried out.

- The first general objective of Clean Sky GRC3 project is the reduction of carbon emissions and improved overall electrical power system energy efficiency. The strategy within the power system work program on emissions is primarily structured to encourage the development of active energy management techniques, directed at reducing overall primary fuel based electrical demand. This includes technologies to allow energy recovery (thermal, kinetic), reducing installed power generation and distribution mass and minimising power losses; improved starter-generators, more efficient and modular power converters, advanced batteries and other energy storage devices (e.g. ultra-capacitors); an electric rotor brake concept capable of recovering rotor kinetic energy after landing; optimized power distribution architectures are research fields under investigation in Clean Sky Green Rotorcraft, but only at concept or subsystem bench test level. Further development in Clean Sky 2 will allow investigation all the way to system integration and flight demonstration.

- Another objective of GRC3 is the replacement of hydraulic systems on rotorcraft by electrically-powered systems. The adoption of Electro-Mechanic Actuators and the scalability of this technology from helicopters and/or fixed wing aircrafts will be carried out, integrated within the full flying vehicle and brought to a higher maturity level.

- Tiltrotors can operate like helicopters, with vertical take-off and landing, as well as like airplanes. This flexibility allows the development of smart solutions for tiltrotor integration into ATM regulation, a primary goal for NextGenCTR project. This activity will fully exploit the advantages of low-noise approaches and departures, eco-friendly routes, efficient interaction with fixed-wing air traffic and maximum use of tiltrotor manoeuvring capabilities, that are R&D themes already investigated in Clean Sky Green Rotorcraft which will be further demonstrated through flight simulation, eligible to be continued also in Clean Sky 2 project, leading to full flight demonstration.

- Innovative materials and processes for aircraft manufacturing can significantly reduce the environmental footprint; within Clean Sky Green Rotorcraft the adoption of thermoplastic materials for structural parts and components manufacturing is being investigated. Compared to traditional thermoset composites, thermoplastics require less energy for raw material storage; they are reparable and can be easily recycled. The final GRC demonstrator is a helicopter tail cone to be compared to a traditional one through static test. The application of this technology to other parts and components and its scalability will be investigated, together with the integration issues which arise in case of a full-vehicle flight demonstration.

- Environmental-friendly coatings for metal alloys (Chromium- and Cadmium-free) are being currently tested in Clean Sky Green Rotorcraft up to a full gearbox static test. Other aspects such as fatigue issues and manufacturing process optimization have not been considered yet, and will be addressed in Clean Sky 2, applying them to tiltrotor components such as the drive system gear-boxes.
8.6.4 NextGenCTR Project Description

NextGenCTR project structure is based on work packages (WP) that constitute the building blocks of the technology demonstrator: prop-rotor, drive system, airframe and structure, engine installation and systems. In each work package, R&T activities will be developed with the purpose to meet the project objectives and validate the solutions and technologies adopted.

The project will include a specific WP to interface NextGenCTR with Clean Sky 2 Technology Evaluator (TE). Transversal Activities, mainly on Eco-design aspects, will be allocated within the WPs and clearly identified. A specific WP is dedicated to the management of the project, interactions with Clean Sky 2 IADPs/ITDs and JTI organization and it will include dissemination activities as well.

The project is conceived to take advantage of results achieved in current Clean Sky GRC programme, and will exploit the know-how acquired through other projects (ERICA, Nicetrip) run in previous framework programmes (FP). Interactions of NextGenCTR project with current GRC and previous FPs’ projects are identified for each specific WP.

Though the backbone of the project relies on WPs where major systems will be developed and R&T activities will be done, Calls for Proposal (CfP) will be published over the whole duration of the project to cover specific topics and needs that will arise during the design and validation activities. It is generally assumed that CfP will be inserted into the single WPs as necessary; however, a few of these Calls are clearly identified in NextGenCTR Master Plan as it is expected these will refer to activities where the complexity of the subjects will be such that substantial budget will need to be allocated: one regards prop-rotor; one is related to anti-/de-icing system; one is provisional and will be allocated as a post-flight demonstration activity.

Specific Call for Tenders (CfT) will be launched to engage sub-contractors.

NextGenCTR’s objectives, at system and platform level, will be pursued by developing major integrated systems, or assemblies, that may be themselves identified as demonstrators in that specific area of the project, in addition to the full scale flight demonstrator platform. These ‘system demonstrators’ are:

- Mock-up (scaled/full-scale) of nose, central section, wing, prop-rotor assemblies
- Major components (blade, hub, rotating control, etc.) and assembly of a low drag and low noise high-efficiency prop-rotor
- Highly reliable, safe and environmental friendly drive system components
- Fuselage and innovative tilting wing test items and assemblies for Tie-Down-Helicopter (TDH)/demonstrator
- Main components of high-efficiency electrical power and distribution systems
- Advanced fly-by-wire (FBW) flight control systems (FCS) components (computers, sensors, actuation system) and system
- Electrical pressurisation system
- Anti-/de-icing advanced technologies and systems

Major ‘system demonstrators’ will be then part of a TDH/full scale flight demonstrator that will validate next generation civil tiltrotor architecture, technologies, systems, operational concepts, demonstrate forward flight speed at 300+ KTS, cruise altitude up to 25,000 ft and long range capacity.

NextGenCTR’s WP structure is shown below, together with a brief description of their content.
**NextGenCTR**

Next Generation Civil Tiltrotor Project

**PROGRAM STRUCTURE**

It includes all the management activities, for the whole duration of CS2 program (2014-2024).

**WP 1.0**
Management

**WP 1.1**
System Integration and Demonstration

Activities include definition of integrated design, and also system integration at demonstrator level; TDH assembly and flight demo. activities are part of this WP.

**WP 1.2**
Efficient Prop-rotor Design & Validation

Design, manufacturing, testing at component level of the prop-rotor system. Research will target drag efficiency, low noise.

**WP 1.3**
Highly Reliable, Safe and Environmental Friendly Drive System

Design, manufacturing and testing at component level of drive system. Research will target safe and reliable design, low environmental impact, low production and operational costs.

**WP 1.4**
Advanced Fuselage and Tilting Wing

Fuselage and wing architecture definition, design, manufacturing, validation. Research will be focused on operating, system integration, low weight, drag efficiency topics.

**WP 1.5**
Engine Installation

Definition and design of engine installation, engine control and fuel systems. Integration with other system will be also done as necessary.

**WP 1.6**
Systems and Equipments

This WP will cover the design, development and testing of the following systems of EPGDS, FCS, ECS. Advanced technologies for ice protection systems will be developed.

**WP 1.7**
Technology Evaluator Interface

TE-related topics regarding regarding tilt-rotor activities will be addressed.

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**Figure 8.4 Next Gen CTR Program Structure**

NextGenCTR project will start in 2014.
There will be an initial phase where NextGenCTR’s basic requirements and objectives will be analysed in detail and general architecture will be defined; a critical design review (CDR) will be held in this phase (WP1.1). Detail research, design and manufacturing will follow. This phase will include the necessary tests (at component and/or system level) and activities for validation purposes and to clear the design for subsequent NextGenCTR flight demonstration (WP1.2 to WP1.6).

An integration and full demonstration phase will follow. This phase will include the validation of systems at integrated level, up to tie-down helicopter (TDH). Tests carried out with TDH, together with other major validation activities performed at system level, will be fundamental to meet the requirements of a flight readiness review meeting (FRR). Successful completion of FRR will allow NextGenCTR’s ground and flight tests demonstration to start. Flight Demonstration is planned to start in 2020 and proceed afterward (WP1.1).

Project timeline, major phases and milestones are shown in NextGenCTR’s Master Plan (MP).

**Project Team, Partnerships and Collaborations**

NextGenCTR is an advanced research and innovation project, and requires the integration of various competences and skills in numerous fields. AgustaWestland will cover the role of global project coordinator and leader and will contribute with its expertise in rotary-wing technologies, research capacity, system integration and testing; other partners may be assigned a role of WP/task leader for a specific activity. The project team will include contributors in the fields of engineering design, structures, advanced materials, aerodynamics, aeroacoustics, wind tunnel testing, advanced systems and equipments, operations simulation. NextGenCTR project is an opportunity for strategic partners to develop technologies as well as for SMEs, research centres and universities committed to advanced research and innovation to have the opportunity to enter the growing sector of Fast Rotorcraft.

**EU Economy and Jobs**

It is well accepted that financial support to R&I programs can favour the growth of companies and other organisations. This was and is still particularly true for aeronautics for which research programs are characterized by high cost and risk, long payback time and in which investments for innovation have been increasing over the last decade even when incremental, rather than radical, improvements are to be achieved. The success of European Union’s R&T and R&I organizations is however expected to provide a positive impact to growth and job creation of the Union. The rotorcraft sector has played its role in favouring economic growth within EU, with own private investments complemented by public support to develop research and innovation programs in pursuit of global leadership. It can be stated that investments, largely self-funded by industry, have brought the two major European rotorcraft OEM to become world leaders12 in the civil market over the last two decades. Today, even in a global economic crisis, the sector is still growing and will provide the possibility to sustain and even increase the 25,000+ jobs of the two EU rotorcraft OEM plus the thousands jobs that are involved in the supply chain, end users and operators, and other stakeholders.

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12 Based on revenues, excluding support, as of 2010.
# Clean Sky 2 Joint Technology Initiative in Aeronautics

## NextGenCTR Master Plan

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**WP1.1 System Integration & Demonstration**

- Requirements Definition & General Architecture
- System Integration & Demonstration
- Demonstration R&T Activities (via CIP)

**WP1.2 Efficient Proprietary Design & Validation**

- Design and Manufacturing (hub, blades, rotating controls)
- Test & validation
- Proprietary Research (via CIP)

**WP1.3 Highly Reliable, Safe & Environmentally Friendly Drive System**

- Design and Manufacturing (PHEG), lubrication system
- Test & Validation

**WP1.4 Advanced Fuselage and Tilting Wing**

- Fuselage Design (Arb / ID)
- Wing Design
- Fuselage & Wing Manufacturing & Testing

**WP1.5 Engine Installation**

- System Design & Integration (Engine Nacelle/Control System, Fuel System)

**WP1.6 Systems & Equipments**

- EPDS / FC3 / ECS Design
- EPDS / FC3 / ECS Manufacturing, Test & Validation
- Anti-Du-Ring Advanced Technologies and Systems (via CIP)

**WP1.7 Technology Evaluator Interface**

- Technology Evaluator Interface

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*Legend:*
- *TRL:* Technology Readiness Level
- *PDR:* Preliminary Design Review
- *EPDS:* Electrical Power Generation System
- *FC3:* Flight Control System
- *ICS:* Instrumentation & Control System
- *Hi-D:** High-Performance
- *DR:** Design Review
- *PRG:** Propulsion Gearbox
- *CIP:* Call for Proposals

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2014 *Clean Sky 2 Joint Technical Programme (V4) – Proprietary Information subject to Confidentiality Agreements*
NextGenCTR will contribute to improve this situation. The project will contribute to open a new segment of air transport and mobility, in line with increasing demand for flexible and smarter mobility solutions. Tiltrotor technology has been recently brought to EU after the acquisition of AgustaWestland of the 609 tiltrotor project from non-EU industry. This will provide a unique opportunity to industry, research centres and university to develop research and innovation programs, supporting the development of competences across EU in various fields of engineering and technologies.

Though future economic growth and jobs creation will depend on various aspects pertaining to global macro-economic and geo-political issues, it is likely to happen that investing and developing on tiltrotor R&I and other rotary-wing programs will support EU growth in the coming years.

AgustaWestland has already experienced this development. The company has grown over the last 20 years through continuous investment in technology and innovation. Thanks to stable R&D expenditure above 10% over the revenues\(^\text{13}\) and innovation programs that have allowed delivering new technologies to respond to market demands, AgustaWestland has been able to guarantee continuous growth of revenues over the last ten years, an increased portion of share over EU aeronautics revenues, excellent productivity\(^\text{14}\), growing headcounts. With regard the workforce and occupation, AgustaWestland has experienced a radical change of company’s population composition and skills: today more than 30% of the employees are less than 35-year old (up from 10% a few years ago), with a steady increase of the share of graduates and of workforce holding post-secondary school higher education qualification. It is expected that R&I activities brought along with NextGenCTR program and future tiltrotor and Fast Rotorcraft development will further support the acquisition of qualified workforce within EU on the medium term to improve current statistics and trends for the company and EU stakeholders globally.

Here below is a summary followed by more detailed description of WPs, tasks, technologies, demonstrators, and estimated budget is shown; (budget is provided in Million Euro, M€; T means Task). TRLs are also provided for each task. Since there activities performed at component or system or aircraft level, TRL is referred to the particular activity performed in that WP or task.

\(^\text{13}\) This value is greater than other competitors and above EU average R&D expenditures (internal AgustaWestland statistics).

\(^\text{14}\) Revenues divided by workforce.
8.6.5  **Management – WP1.0**

**Budget:** ~3.4 M€ Gross, i.e. 1.7 M€ EU funding required.

It includes the management activities specific to the NextGenCTR demonstrator platform, for the whole duration of *Clean Sky 2* Program (2014-2024).

8.6.6  **System Integration and Demonstration – WP1.1**

This WP deals with system integration activities that are needed at both initial and final stages of the entire program. Initially, the concept of NextGenCTR is defined, including general architecture and integrated system design. Mock-up of major airframe sections and rotor are developed as demonstrators. This WP also includes the integration and demonstration activities carried out on TDH and NextGenCTR flight demonstrator. In particular, demonstrators D1, D2 and D3 refer to a succession of progressively more refined artifacts that will start as ground based mock-ups and will be upgraded to major structural components of the TDH (tie-down helicopter, a ground based functional test rig composed by the actual aircraft devoid of some systems, secured to a ground structure and used for component and drivetrain testing in support of flight clearance). After successful accomplishment of the ground based testing, the test article would be upgraded to become the actual flight vehicle by selective introduction of flight rated components where necessary. The specific breakdown of the individual demonstrators will be specified in the work description of the related calls for proposal. The estimated budget is 46.0 M€.

Demonstrator, technologies, links to *Clean Sky 2* pillars, contributors and ROM budget are as follows:
## Clean Sky 2 Joint Technology Initiative in Aeronautics

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Main Actors</th>
</tr>
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</table>
| D1: Mock-Up Of Major Airframe Sections And Rotor | System design  
Structural and dynamics modelling and analysis software  
Advanced electrical system  
Aerodynamics/ aeroacoustics modelling and analysis  
Prototyping technologies | CO$_2$: $\sim$17% (globally)  
Noise: $\sim$7%, $\sim$3dB (globally) | Operational flexibility (new architecture) | Noise reduction to favour flight close to populated areas | 2016 | AW + engineering organisations and universities |
| D2: Tie-Down Helicopter (TDH) | | | Lower empty weight, higher payload | Higher operational flexibility (e.g., take-off/ landing mode) | 2018/2019 |
| D3: NextGenCTR Flight Demonstrator (Ground & Flight) | | | Improved internal comfort  
System safety  
Lower operating cost  
Higher speed  
Higher efficiency and Productivity | Higher speed  
Higher efficiency and Productivity | 2019/2020 |
NextGenCTR’s CO₂ Reduction Objectives

The savings in CO₂ emissions at rotorcraft level are provided in terms of drag efficiency and refer to airplane mode at fast forward flight speed.

Global drag efficiency is expressed in percent with respect to baseline, and it is provided by various contributions of different systems, like prop-rotor, airframe design, engine installation. Baseline is elaborated from available data referring to tiltrotor under development combined with other platform’s architecture studied in previous research programs (ERICA, Nicetrip projects).

CO₂ emissions reduction roadmap for NextGenCTR is summarised in the following table. Drag efficiency improvements vs. the baseline is obtained by both incorporating results from previous research activities and also newer research specific to Clean Sky 2. The “added value” provided by NextGenCTR activities in Clean Sky 2 (with respect to current research programs) will be the flight demonstration at full-scale of the various contributions. It is worth noting that this roadmap does not take into account contributions from turbo-shaft engines from which further CO₂ emissions reductions are envisaged.

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<th>Saving, Topic</th>
<th>Method</th>
<th>Program</th>
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<td>~5% fuselage drag reduction</td>
<td>numerical analysis</td>
<td>Clean Sky</td>
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<tr>
<td>~5% engine installation optimization (intake, exhaust)</td>
<td>wind tunnel tests</td>
<td>Clean Sky</td>
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<tr>
<td>~2% fuselage drag reduction</td>
<td>numerical analysis (1)</td>
<td>Clean Sky 2</td>
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<tr>
<td>~5% prop-rotor efficiency</td>
<td>numerical analysis/test (2)</td>
<td>Clean Sky 2</td>
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Note (1): final flight demonstration will be carried out.
Note (2): wind tunnel tests will be done; final flight demonstration using NextGenCTR technology demonstrator will be carried out.

NextGenCTR’s Noise Reduction Objectives

Noise reduction objectives at rotorcraft level refer to take-off and landing phases, which are the most critical for rotorcraft.

Similar considerations done for drag efficiency/CO₂ with regard to baseline are valid here (i.e., baseline is defined based on data referring to tiltrotor under development, adapted to the architecture of the other platform, as studied in previous research programs). Noise emissions reduction is expressed in terms of percentage (%) of change of footprint of perceived noise levels and also absolute noise value (dB), similarly to the practice in use in current Clean Sky. The noise cut is expected to come from improved prop-rotor design and flight trajectory management. Contribution from turbo-shaft engines is not taken into consideration on the short term (2020), while the effect of engines is considered provisionally in the achievements expected from 2020 to 2030.

Noise emissions reduction roadmap is summarised in the following table:

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<th>Savings, Topic</th>
<th>Method</th>
<th>Program</th>
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Clean Sky 2 Joint Technology Initiative in Aeronautics

5% prop-rotor aeroacoustics improvements

2% flight trajectories

3 dB, prop-rotor aeroacoustics, flight trajectories analysis, tests

Numerical analysis, test (1)

Wind tunnel tests

Clean Sky

Clean Sky/Clean Sky 2

Clean Sky/Clean Sky 2

post-Clean Sky 2 R&T, from 2020 to 2030

–13% with contributions from:
  prop-rotor aeroacoustics optimization
  prop-rotor variable speed control
  prop-rotor active blade control
  engine noise reduction

Analysis, tests

post-Clean Sky 2 R&D

Considerations about Industrial Leadership objective

‘Industrial Leadership’ may be referred to as how good an industry is in becoming the reference in defining the state-of-the-art trends (technologies, products, services) and reaching a healthy, economically sustainable growth thanks to sales driven by the capacity to meet market demands.

There are various and diversified elements, internal and external to organizations, that contribute to developing a leadership role. In this context the contribution provided by research and technology (R&T) is considered, and how these impact the specific type of aircraft, i.e. tiltrotor.

The domains in which R&T can improve tiltrotor to provide higher standards and favour a leading position in rotorcraft are expected to be:

Reduced cost of ownership

It refers to i) cost of acquisition of the aircraft, ii) low operating cost, and iii) efficiency with regard to the specific activities and missions for which the platform is used, that together influence global costs for users and operators. With regard to items ii) and iii) a dedicated focus is provided later. Cost of acquisition is addressed by reducing cost (complexity and duration) of research, technology and development (RT&D) tasks, including certification activities and cost of production. Steps ahead with this respect may be obtained introducing more streamlined processes (e.g., less testing, more simulation, etc.), lower production costs thanks to new processes (reducing the time and the cost of the specific processes, e.g. new material/production techniques, etc.).

Low operating costs

Lowering costs of operation is possible by reducing the cost of fuel consumed; NextGenCTR project will address this by exploiting the increased drag efficiency provided by aerodynamic improvements of airframe (fuselage, wing, nacelle), and prop-rotor. A drag reduction of –17% by 2020 is expected.

It may be stated that a fuel burn reduction of 10% may allow an operating cost reduction ranging from 2% to 4%, depending on type of application and mission profile\textsuperscript{15}.

Maintenance, Repair & Overhaul (MRO) Costs

Costs for MRO constitute a large portion of operating costs of a rotorcraft: reducing these costs is fundamental to achieve a more favourable position with respect to operational needs. To reduce MRO costs innovative and advanced technologies, engineering and production solutions need to be pursued: high level of system integration, damage tolerant airframe and structure, use of health and usage monitoring systems (HUMS), condition based maintenance approaches, increasing the reliability at equipment level are some of them. It is therefore expected that advanced engineering design and system integration, extensive use of sensors to

\textsuperscript{15}AgustaWestland internal projections, based on in-service helicopters (it depends on operating costs model).
monitor status of airframe, structures and systems, built-in fault detection function of equipments, systems tolerant to flaw and damages, etc. will contribute to reduce MRO costs. NextGenCTR airframe, prop-rotor, drive systems will adopt solutions that will address the reduction of MRO costs.

**Fast Forward Speed**
Fast Rotorcraft provides the architectural solutions and technologies that will allow rotorcraft to fly in economically at speeds ranging from 200 to 350 knots in forward flight, speeds today not attainable by conventional helicopter architectures, while retaining excellent hover and low speed performance and handling qualities. Though not the only one, high speed is the key advantage of Fast Rotorcraft: it will provide the possibility to shorten the flight time when this becomes essential for mission effectiveness. NextGenCTR’s target is to fly at a cruise speed greater than 300 knots. An industry that is able to provide high speeds rotorcraft (comparable to fixed-wing platforms) with good hover performance in an efficient solution is expected to meet a clear market expectation and will provide the opportunity to play a leadership role in the growing domain for Fast Rotorcraft to address various missions (transport, search and rescue, life savings, special applications, public utilities, etc.)

**High Efficiency, High Productivity**
Item iii) introduced in the ‘Reduced cost of ownership’ section above is related to the productivity that Fast Rotorcraft, and hence NextGenCTR, are expected to provide. Productivity needs also to be cross-checked with the efficiency with which that productivity is generated.
When analysing the efficiency or the productivity of a platform for a specific mission in rotorcraft domain, indexes are often used: they are useful to measure the “performance” of that platform, and and may be complemented by roadmaps that show trends and improvements.

An Efficiency Index (EI) may be introduced to show how efficient is the use of energy with respect the type of mission required. EI may be defined as transported payload \( P \) over a range \( R \) divided for fuel used, thus providing the transported payload times distance per unit fuel burn. The inverse of EI provides a cost index \( CI \) and provides the cost (of fuel) to transport the unit payload per unit distance. Current tiltrotor platforms are more productive than average conventional helicopters. On the other hand in short and medium term, advanced tiltrotor architectures can target 50% more productivity as helicopters. Improving (increasing) EI is possible by reducing the empty weight and burning less fuel, thereby increasing the range (considering other parameters fixed).

A Productivity Index (PI) may be used to show how productive a specific mission is (i.e., how much work is done in how much time); PI includes a speed term to show the contribution of speed (time) to carry out a specific mission. PI may be defined as the transported payload \( P \) at a distance and per unit time, hence at which speed; payload may be also expressed in terms of fraction (percentage, \( P_{\%} \)) of maximum gross weight (MGW). Thanks to its superior speed but also good payload capacity, today tiltrotors are more productive than conventional helicopters. NextGenCTR is expected to carry out a typical search and rescue or emergency medical service mission, with a radius of 250 NM in one hour and 45 minutes (i.e., from home base to destination, back to home base, hover included). Next generation tiltrotors can further increase this gap and approach typical PI values of turboprops. Decreasing empty weight (i.e., increasing payload fraction), increasing forward flight speed will allow further improvement of productivity.

**Air Mobility**
NextGenCTR will contribute to generate a wider offer with respect to current spectrum of air mobility possibilities. Its intrinsic characteristics of good hover capabilities with fast forward speed comparable to turboprop provide more flexible solutions to fulfil demand for smart transportation and various services. NextGenCTR will be able to carry out vertical take-off and landing (VTOL), as well as a pure airplane mode when required by particular air traffic needs, or when it is convenient for the effectiveness of the mission and operations.

A combination of improved ground services (greater integration with other transportation means, exploitation of existing take-off and landing infrastructure – either airport or heliport/vertiport – advanced communication services, etc.) plus the VTOL and high speed in forward flight capabilities of NextGenCTR tiltrotor, will make Flightpath 2050 goal for 4-hours door-to-door travel across Europe a possibility that can be reached on more medium term 2020-2030.

WP1.1 structure will be as follows:

![WP1.1 Structure Diagram]

Figure 8.5 WP1.1 Structure
Programme plan for WP1.1 is as follows:

### NextGenCTRL Master Plan

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<td>T1.1.4 Post-flight Demonstration R&amp;D Activities (via CfP)</td>
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### Inputs From Other R&I Programs
- CS-GRC2 Optimised geometry of common TR (ERICA)
- CS-GRC3 Improved electrical network & power management
- CS-GRC4 Innovative energy storage & distribution
- CS-GRC5 Eco-flight procedures for TR (low noise trajectories)
- CS-GRC6 Tools for eco-flight mission planner & real-time guidance

### ERICA/Nicetrip
- concept, design
- manufacturing, testing
- Integration tests and full demonstration
- research via CfP (selected)

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2014 Clean Sky 2 Joint Technical Programme (V4) – Proprietary Information subject to Confidentiality Agreements
**Task 1.1.1 Concept & Integrated System Design**

This task is related to the initial stage of the project and it deals with requirements definition, studies, pre-design, general architecture at global and system level, down-selection of technologies, and integrated design. Activities are split in a task 1.1.1a (Aircraft Requirements Definition & General Architecture) and 1.1.1b Integrated System Design. A critical design review (CDR) is planned to freeze the design and the general architecture.

Engineering activities of modelling and analysis and various topics will be covered to meet the project’s objectives: system design (proprotor, drive system, airframe), aerodynamics/aeroacoustics, structural design and general architecture. Activities will be mainly those typical of a preliminary design phase. The main deliverable will be the architecture definition.

It is planned to deliver a full scale mock of the fuselage and proprotor, of suitable size (demonstrator D1). These may be used to show and validate the solutions adopted and allow conceptual design review for future solutions.

TRL (aircraft design) progress within the task: from 3 to 4

**Task 1.1.2 System Integration and Validation**

This task covers the assembly of a tie-down-helicopter (TDH) and execution of integration tests. TDH will be equipped with the major structural (fuselage, wing) and dynamic systems (proprotor, drive system, engines and associated systems), it will run on ground and will provide the first validation at integrated level of the technologies. TDH will include appropriate control and monitoring systems required for effective and safe control. The TDH is considered a demonstrator in its nature (demonstrator D2), and the integration tests conducted will contribute to clear flight demonstration on NextGenCTR demonstrator tiltrotor.

TRL (aircraft design) progress within the task: from 4 to 5

**Task 1.1.3 NextGenCTR Ground / Flight Tests Demonstration**

After TDH tests, the test article will be upgraded to NextGenCTR final configuration and be tested on ground. Final stage is the demonstration in flight (demonstrator D3). This will cover validation of architecture, technology & systems validation and operational concepts.

Appropriate readiness review meetings will guarantee safety during ground and flight tests.

TRL (integrated aircraft) progress within the task: from 5 to 6

**Task 1.1.4 Post-flight demonstration R&T activities**

It is expected that the flight validation activities will identify one or more research topics worthy of significant further investigation. It is planned that one or more of them will be selected on the basis of the results of validation activities and a Call for Proposal will be launched. The budget allocated will be substantial to guarantee a project size that can ensure post-Clean Sky 2 research programs and continuation with a tiltrotor roadmap in 2020-2030 timeframe. Specifically it is expected that this package will include expansion of the initial limited flight envelope to fully exploit the capabilities of the vehicle architecture. It will also include integration of selected systems that might have initially been developed as ground based demonstrators only as
they would not have been mandatory for the first flight test demonstration phase (e.g. complete air management system, icing protection system, etc.).

8.6.7 Efficient Prop-rotor Design & Validation – WP1.2

This WP deals with the definition of the design, the manufacturing and testing at component level of the proprotor. Research activities will focus on drag efficiency to meet low drag and low fuel burn for reduced CO₂ emission targets, and adopt solutions to match noise objectives. The estimated budget is 22.4 M€.

WP1.2 will allow definition and manufacturing of proprotor. Availability of proprotor component and assembly must be regarded as a demonstrator for this WP.
Demonstrator, technologies, links to *Clean Sky 2* pillars, contributors and ROM budget are reported in the following table. Values in ‘Greening’ column refer to prop-rotor’s contribution only:

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Main Actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>D4: Prop-Rotor Components And Assembly</td>
<td>System design and integration</td>
<td>CO₂: −5%</td>
<td>Low operating cost</td>
<td>Low operating cost</td>
<td>2018/2019</td>
<td>AW + providers of rotor components (bearings, dampers, rods,...), + research establishments with testing and wind tunnel capabilities</td>
</tr>
<tr>
<td></td>
<td>Structural and dynamics modelling and analysis software</td>
<td>Noise: −5%, −1dB</td>
<td>Low external noise and improved internal comfort</td>
<td>Low noise impact</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aerodynamics/aeroacoustics modelling and analysis</td>
<td></td>
<td>Higher speed</td>
<td>Higher productivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wind tunnel testing</td>
<td></td>
<td>Higher efficiency &amp; productivity</td>
<td>Higher productivity</td>
<td></td>
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</tr>
</tbody>
</table>
WP1.2 structure will be as follows:

- **T 1.2.1** Prop-rotor Detail Design
- **T 1.2.2** Prop-rotor Components Manufacturing
- **T 1.2.3** Prop-rotor Testing & Validation
- **T 1.2.4** Prop-rotor R&T Topic (via CIP)

*Figure 8.6 WP1.2 Structure*
Programme plan for WP1.2 is as follows:
**Task 1.2.1 Proprotor Detail Design**

This task will use preliminary design done in WP1 as input. Detail design will cover proprotor components (blades, hub, fixed/rotating controls, etc.) as well as proprotor assembly and installation. The activity will deal with the sizing and system design to comply with requirements about kinematics, loads and acoustics, with the purpose to meet NextGenCTR objectives (static, fatigue, aerodynamics, aeroelastic, aeroacoustics). Engineering modelling and analysis are extensively done in this phase, and structural, aerodynamic, aeroelastic, aeroacoustic analysis competence within the design team is necessary. Compliance to airworthiness requirements needs to be covered in this context also, in view of the release of ‘Permit to Fly’ from the Aviation Authorities for ground and flight demonstration activities.

Main deliverables: proprotor design and installation assembly.

TRL (system design) progress within the task: from 3 to 4.

**Task 1.2.2 Proprotor Components Manufacturing**

Manufacturing and testing at component level will be part of this WP. Testing will cover validation of the design on the specific components (control rods, structural elements, blades, spinner, etc.). Activities addressing manufacturing of proprotor components will cover most innovative items and will be related to construction of test specimen and parts for tie-down helicopter (TDH) and parts installed to final demonstrator aircraft and brought to flight. Specific validation tests (structural, environmental) will be performed to validate the design and guarantee the subsequent flight clearance.

Main deliverables: proprotor components.

TRL (component level) progress within the task: from 4 to 5.

**Task 1.2.3 Proprotor Testing & Validation**

Testing and validation (mainly structural tests and wind tunnel tests) to confirm design assumptions, check compliance with requirements, and clear subsequent flight demonstration activities.

Wind tunnel tests will be conducted to validate aerodynamics and aeroacoustics characteristics of blade design and proprotor configuration. With regard to the link between proprotor definition and design towards NextGenCTR objectives, the research activity will include aerodynamic studies and development of solution to seek for substantial aerodynamic efficiency leading to CO₂ emission reduction, as well as aeroacoustics efficiency towards noise reduction. It is expected that optimized proprotor solutions (blade and tip design, spinner geometry, proprotor speed variation in different flight regimes, etc.) can bring to a CO₂ cut of −5%, and noise emissions reduction of −5% / −1db.

Main deliverables: proprotor components’ tests results.

TRL (component level) progress within the task: from 5 to 6.

**Task 1.2.4 Proprotor Research Topic via CfP**

During and after ground/flight validation activities, and to launch post-2020 activities within Clean Sky 2, a research topic will be selected and a Call for Proposal will be published. The budget allocated will be substantial to guarantee a project size that can ensure post-Clean Sky 2 research programs and continuation with a tiltrotor roadmap in 2020-2030 timeframe.
8.6.8 Highly Reliable, Safe and Environmentally Friendly Drive System – WP1.3

This WP refers to the definition of the design, the manufacturing and testing at component level of NextGenCTR drive system (DS).

The DS configuration and detailed design shall be managed in a fully integrated way with the structure and systems, in order to achieve the best compromise among main targets, namely design features for safe and reliable operations, low environmental impact, low production and operational costs. The estimated budget is 19.8 M€.

This WP will deliver the DS of NextGenCTR, which can be regarded as a demonstrator.
Demonstrator, technologies, links to *Clean Sky 2* pillars, contributors and ROM budget are as follows:

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Main Actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS: NextGenCTR’s Drive System Components and Assembly</td>
<td>Advanced materials for low environmental impact, Design-to cost criteria, Design-to weight criteria, Safe operation for “no-oil” emergency</td>
<td>Reduced impact on environment (advanced manufacturing process) (globally)</td>
<td>High design and operational, safety and performance standards, Low weight/ cost Design, Reduced environmental impact</td>
<td>Low maintenance design, Highest standards for safe operation in emergency conditions</td>
<td>2018/2019</td>
<td>AW + systems suppliers and partners</td>
</tr>
</tbody>
</table>
WP1.3 structure will be as follows:

![Figure 8.7 WP1.3 Structure](image-url)
Programme plan for WP1.3 is as follows:

### NextGenCTR Master Plan

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>T1.3.1: Drive System Architecture Definition</td>
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<tr>
<td>PDR - Preliminary Design Review</td>
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<td>T1.3.2: Drive System Design</td>
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<td>CDR - Critical Design Review</td>
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<tr>
<td>T1.3.3: Drive System Components Manufacturing</td>
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<tr>
<td>T1.3.4: Drive System Testing &amp; Validation</td>
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</tbody>
</table>

**Inputs From Other R&I Programs**

- CS-GRC: Environmentally friendly metal alloy coatings
- BRICA/Nicetrip

Legend:
- **concept, design**
- **manufacturing, testing**
- **integration tests and full demonstration**
- **research via CIP (selected)**

**Milestones**

- **PDR**: Preliminary Design Review
- **CDR**: Critical Design Review
- **FRR**: Flight Readiness Review
- **DR**: Tie-Down Helicopter
- **PRGB**: Proprotor Gear Box

**Assessments**

- **TRL**: Technology Readiness Level
- **Airfr. TTD**: Airframer TTD
- **Airfr. ETD**: Airframer ETD
- **CIP**: Call for Proposal
- **PCS**: Flight Control System
- **ECS**: Environmental Control System
- **EPGS**: Electrical Power Generation Distribution System
- **PRGB**: Proprotor Gear Box
Task 1.3.1 Drive System Architecture Definition

A detailed feasibility study shall address different possible design architectures, in order to reach the best trade-off taking into account: engine installation, integration of proprotor and proprotor actuator system, actuation of movable wing and aileron, integration of accessories, nacelle structure and aerodynamics, weight, environmental impact and possibility to inspect. The minimization and optimization of meshing couples and internal lubrication management will target losses reduction and efficiency optimization. Accessories such as heat exchangers, cooling fans, hydraulic pumps and electrical devices shall be designed and integrated for reduced overall weight, low volume and high efficiency. Main deliverables: gearbox architecture and system description. TRL (system level) progress within the task: from 2 to 3.

Task 1.3.2 Drive System Design

Detail design is done in order to comply with static and fatigue requirements, safety and reliability and low environmental impact. In order to maximise the safety of the design, these fundamental aspects will be investigated: gear box no-oil capability, damage detectability, fretting phenomena prediction and mitigation, crack and flaw tolerance design approach. New materials and related technological manufacturing processes (i.e. advanced polymers, additive manufacturing technologies and new alloys) will be considered in the design. The exploitation of these technologies to support innovative structural architectures for the drive system components will be investigated. The use of environmentally friendly materials and processes will be a considerable part of the project: starting from the preliminary evaluations within Clean Sky GRC6.3, the technologies will be part of the design that will be validated in flight. Main deliverables: drive system design and installation assembly. TRL (system level) progress within the task: from 3 to 4.

Task 1.3.3 Drive System Components Manufacturing

Main deliverables for this task will be the drive system components, which will be subject to structural and functional tests to validate design assumptions. Also, complete drive systems sub-assemblies will be delivered to run bench and TDH tests. Main deliverables: drive system components and sub-assemblies. TRL (component level) progress within the task: from 4 to 5.

Task 1.3.4 Drive System Testing & Validation

Testing and validation will be articulated into: structural static and fatigue tests on materials coupons and components, bench tests on complete gearboxes for pattern development and gears fatigue in order to validate design assumptions, verify compliance with airworthiness requirements, and give clearance to flight demonstrator operations. Finally TDH endurance will complete the validation (this is part of WP1.1). Significant effort will be spent in dedicated test rig and test bench design, acquisition, set up and operation in this task. Main deliverables: results of testing activities, reporting. TRL (system level) progress within the task: from 5 to 6
8.6.9 Advanced Fuselage and Tilting Wing – WP1.4

This WP deals with architecture definition, design, manufacturing and validation of fuselage (nose, center and, tail assemblies) and wing. The fuselage will functionally divided in three major section due to the specific structural and functional requirements of each unit. The design of the nose will address structural considerations and operational issues (advanced aerodynamics, compliance with birdstrike requirements, integration of sensors, excellent pilot visibility for confined area operations, accessibility and maintainability of all installed systems). The center fuselage section will need to fulfil several challenging requirements simultaneously. It will need to provide a suitable environment for passenger accommodation while retaining the necessary configuration flexibility to accommodate alternative mission equipment layouts. It will act as structural link between the wing, nose, tail and landing gear, absorbing and redistributing the ground and flight loads under all operational conditions. It will need to provide adequate strength to withstand regular flight loads as well as emergency landing load conditions. It will require low manufacturing cost and simple maintainability to support operations in unprepared areas. The tail section will support the aft aerodynamic surfaces and will potentially house the auxiliary power unit (APU) providing appropriate strength, stiffness and fire containment and system separation with minimal weight. The activities related to the fuselage design, manufacturing and testing shall be performed in the Airframe ITD. The wing will include a fixed inboard portion and a tiltable outboard portion. The wing will need to provide optimal aerodynamic efficiency in forward flight and minimal interference during hovering flight in helicopter mode. It will provide integral fuel storage, moveable flight control surfaces, lift augmentation systems while housing several systems, including the interconnecting driveshaft linking the two proprotors for operation in single engine conditions. It will need to include provisions for icing, lightning and electromagnetic protection of the structure and of the systems contained within. The wing will need to fulfil challenging strength and stiffness requirements under all operating conditions, both in airplane and helicopter mode, with particular attention to the aeromechanical stability issues associated with the proprotor integration (whirl flutter). The research and validation activities will need to address aerodynamic efficiency, structural integrity and system integration issues. The estimated budget is 67.6 M€.

Fuselage and wing assembly can be considered demonstrators for this WP.
Demonstrator, technologies, links to *Clean Sky 2* pillars, contributors and ROM budget are as follows:

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Main Actors</th>
</tr>
</thead>
<tbody>
<tr>
<td>D6: NextGenCTR’s Fuselage Assembly</td>
<td>Aerodynamics modelling and analysis</td>
<td>CO₂: ~7% Low drag, low weight design</td>
<td>High Performance, Design, Operational And Safety Standards</td>
<td>Optimal Operating Procedures In Both Airplane And Helicopter Mode</td>
<td>2018/2019</td>
<td>AW + airframers + systems suppliers and partners</td>
</tr>
<tr>
<td>D7: NextGenCTR’s Wing Assembly</td>
<td>Structural modelling, analysis, testing</td>
<td></td>
<td>Ease Of Operation In All Flight Phases Low Weight/ Cost Design</td>
<td>High Standards For Safe Operation In Emergency Conditions (Crashworthiness) High Forward Flight Speed Design High Efficiency, Productivity</td>
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<td></td>
<td>Advanced composite, metallic materials</td>
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<td>Reduced Environmental Impact</td>
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<tr>
<td></td>
<td>Complex system design modelling and analysis</td>
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<td></td>
<td>Design-to cost criteria</td>
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<td></td>
<td>Design-to weight criteria</td>
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</table>
WP1.4 structure will be as follows:

![Diagram of WP1.4 structure]

Figure 8.8 WP1.4 Structure
Programme plan for WP1.4 is as follows:

<table>
<thead>
<tr>
<th>NextGenCTR Master Plan</th>
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<tr>
<td>WP1.4 Advanced Fuselage and Tilting Wing</td>
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<tr>
<td>T1.4.1 Fuselage Nose Design, Manufacturing &amp; Testing (Airfr. ITD)</td>
</tr>
<tr>
<td>T1.4.2 Fuselage Central Section Design, Manufacturing &amp; Testing (Airfr. ITD)</td>
</tr>
<tr>
<td>T1.4.3 Fuselage Tail Section Design, Manufacturing &amp; Testing (Airfr. ITD)</td>
</tr>
<tr>
<td>PDR - Preliminary Design Review</td>
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<td>CDR - Critical Design Review</td>
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<td>T1.4.4 Wing Design, Manufacturing &amp; Testing</td>
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</tr>
</tbody>
</table>

- **TRL**
- **PDR** - Preliminary Design Review
- **CDR** - Critical Design Review
- **TDH** - Tie Down Helicopter
- **CS-QRC6** - Composite thermoplastic structural parts

**Inputs From Other R&I Programs**

- **EPGS** - Electrical Power Generation & Distribution System
- **FCS** - Flight Control System
- **ECS** - Environmental Control System
- **PRGB** - Propeller Gear Box

**Legend**

- concept, design
- manufacturing, testing
- integration tests and full demonstration
- research via CP (selected)
Task 1.4.1 Fuselage Nose Design, Manufacturing and Testing

Engineering activities of modelling, analysis and design of the front portion of the fuselage to include nose, cockpit and front landing gear bay. Specific challenges will be the weight efficient design of a structure capable to withstand aircraft-type operating conditions (high speed, pressurization and de-icing requirements with efficient aerodynamic shape) while satisfying helicopter-type operational requirements (good visibility for confined area operations, birdstrike, crashworthiness and ditching capability, minimal weight and suitable robustness for unimproved area operation, ability to accept multiple sensor packages for mission flexibility). The design objectives of minimal drag and weight are aimed at enabling NextGenCTR CO₂/noise emission reduction targets by reduction of the power required in all phases of flight.

The objective will be pursued by means of an optimal design leveraging dedicated selection of materials and manufacturing technologies (including but not limited to hybrid composite-metallic structures, automated tape laying for single piece outer skin, lightweight hybrid transparencies for de-icing and bird strike resistance, use of thermoplastic matrix composites from initial conception).

Manufacturing of physical components for testing and for assembly of technology demonstrator will be part of this task.

The fuselage nose will be structurally tested on dedicated benches to support flight clearance. Individual sub-assembly tests will be performed as required.

Main deliverables: fuselage nose architecture description, physical components for testing and for assembly of technology demonstrator.

TRL (system level) progress within the task: from 3 to 6

Task 1.4.2 Fuselage Central Section Design, Manufacturing and Testing

Engineering activities of modelling, analysis and detail design of the central portion of the fuselage to include passenger compartment, access doors, wing-to-fuselage interface, baggage compartment and main landing gear bays. Specific challenges will be the weight efficient design of a structure capable to withstand aircraft-type operating conditions (high speed and pressurization with efficient aerodynamic shape, resistance to flight and high-speed landing loads) while satisfying helicopter-type operational requirements (crashworthiness and ditching capability, minimal weight and robustness for unimproved area operation, ability to be reconfigured internally for mission flexibility, low MRO costs). The design objectives of minimal drag and weight are aimed at enabling NextGenCTR CO₂ and noise emission reduction targets by reduction of the power required in all phases of flight.

The objective will be pursued by means of an optimal design leveraging dedicated selection of materials and manufacturing technologies (including but not limited to hybrid composite-metallic structures, automated tape laying for single piece outer skin, use of thermoplastic matrix composites from initial conception).

The fuselage will be structurally tested on dedicated rigs to support flight clearance. Individual sub-assembly tests will be performed as required.
Manufacturing of physical components for testing and for assembly of technology demonstrator will be part of this task.

Main deliverables: fuselage centre section architecture description, physical components for testing and for assembly of technology demonstrator.
TRL (system level) progress within the task: from 3 to 6

**Task 1.4.3 Fuselage Tail Section Design, Manufacturing and Testing**

Engineering activities of modelling, analysis and detail design of the tail portion of the fuselage to aft fuselage tail cone, horizontal and vertical tail surfaces, both fixed and moveable. Specific challenges will be the weight efficient design of a structure capable to withstand aircraft-type operating conditions (ability to resist flight loads while providing minimal aerodynamic resistance and required longitudinal and lateral control forces for forward flight) while satisfying helicopter-type operational requirements (stiffness, crashworthiness and ditching capability, minimal weight and robustness for unimproved area operation, limited footprint for operational flexibility in confined areas). The tail cone will also house the Auxiliary Power Unit (APU) and appropriate provisions for it will have to be developed. The design objectives of minimal drag and weight are aimed at enabling NextGenCTR CO₂ and noise emission reduction targets by reduction of the power required in all phases of flight.

The objective will be pursued by means of an optimal design leveraging dedicated selection of materials and manufacturing technologies (including but not limited to hybrid composite-metallic structures, automated tape laying for single piece outer skin, use of thermoplastic matrix composites from initial conception).

The fuselage will be structurally tested on dedicated rigs to support flight clearance. Individual sub-assembly tests will be performed as required.
Manufacturing of physical components for testing and for assembly of technology demonstrator will be part of this task.

Main deliverables: fuselage tail architecture description, physical components for testing and for assembly of technology demonstrator.
TRL (system level) progress within the task: from 3 to 6

**Task 1.4.4 Wing Design, manufacturing and testing**

Engineering activities of modelling, analysis and detail design of the wing, including fuselage interface, fuel tanks, lift augmentation devices, movable control surfaces, tilting wing tubular spar and tilting wing including ailerons and nacelle interfaces. Specific challenges will be the weight efficient design of a structure capable of providing necessary aerodynamic efficiency in aircraft mode while insuring adequate stiffness for aeroelastic stability during both aircraft and helicopter mode flight phases. The design of the tilting wing, with associated control surfaces, will require definition of innovative bearing installations to allow unrestricted tilting under flight loads and operability in adverse environment. Routing of services between different portions of the wing will require innovative design for interconnection assemblies (hoses, tubing, wiring harnesses). The design will require
extreme efforts in weight control, while maintainability and serviceability will be fundamental for the economic viability of the aircraft as a whole.

The objective will be pursued by means of an optimal design leveraging dedicated selection of materials and manufacturing technologies (including but not limited to hybrid composite-metallic structures, use of thermoplastic matrix composites from initial conception, integration of fuel containment provisions and provisions for de-icing, lightning and electromagnetic protection).

Manufacturing of physical components for testing and for assembly of technology demonstrator will be part of this task.

The wing will be structurally tested on dedicated benches to support flight clearance. Individual sub-assembly tests will be performed as required.

Main deliverables: wing architecture description, physical components for testing and for assembly of technology demonstrator.
TRL (system level) progress within the task: from 3 to 6.

**8.6.10 Engine Installation – WP1.5**

It includes the definition and design of engine installation, as well as of the engine control and fuel systems. Activities in this WP are related to the integration of specific systems associated to engine installation with NextGenCTR’s airframe and systems.

Engine installation focused &T will be aimed at optimal integration of engine with airframe, from the point of view of tiltrotor’s aerodynamic performance and integration with supporting structure and systems (electrical, fuel, etc.). Aerodynamic optimization of intake and exhaust will provide optimal overall engine performance throughout the flight regimes. Intake and exhaust flow management will target drag minimization of the complete engine installation in high speed cruise, therby contributing to the overall objective of emission reduction. Provisions for intake air filtering will account for planned operations in adverse environments. Engine Control specific task covers the integration of the control laws of the engine with the peculiar needs of NextGenCTR’s flight control laws and flight mechanics requirements. Task related to fuel systems covers the development of fuel system architecture, main components development, and harmonization with tiltrotor requirements (for example crashworthiness).

The engine will be an adaptation of an existing commercially available turboshaft of adequate performance. The engine manufacturer will be responsible for the tailoring of the engine to the specific platform requirements and for the development of data in support of flight clearance for engine and related installation.

The estimated budget is 18.0 M€.
Demonstrator, technologies, links to *Clean Sky 2* pillars, contributors and ROM budget are as follows:

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Main Actors</th>
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</thead>
<tbody>
<tr>
<td><strong>D8: Engine-Airframe Physical Integration</strong></td>
<td>Aerodynamics modelling and analysis</td>
<td><strong>CO₂ : – 5%</strong></td>
<td>Low drag design</td>
<td>Optimal operating Procedures in both airplane and helicopter mode</td>
<td>2018/2019</td>
<td>AW</td>
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<td></td>
<td>Advanced system modelling, simulation and integration</td>
<td>Low drag Design</td>
<td>High standards on Safety (crashworthiness) and operational flexibility (icing conditions)</td>
<td>High standards on Safety (crashworthiness) and operational flexibility (icing conditions)</td>
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<td>+ engine OEM</td>
</tr>
<tr>
<td></td>
<td>Testing techniques</td>
<td>Reduced environmental impact</td>
<td></td>
<td>High efficiency, Productivity</td>
<td></td>
<td>+ systems Suppliers and Partners</td>
</tr>
<tr>
<td><strong>D9: Fuel System Components</strong></td>
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WP1.5 structure will be as follows:

![Diagram of WP1.5 structure](image-url)

Figure 8.9 WP1.5 Structure
Programme plan for WP1.5 is as follows:

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<th>WP1.5 Engine Installation</th>
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<td>T1.5.1 Nacelle Design &amp; Validation</td>
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<td>T1.5.2 Fuel System Design &amp; Integration</td>
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<td>T1.5.3 Engine Control System Design &amp; Integration</td>
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<td>PDR - Preliminary Design Review</td>
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<td>CDR - Critical Design Review</td>
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**Inputs From Other R&I Programs**
- CS-GRC2 Optimised TTR turboshaft installation

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<th>Year</th>
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Legend:
- Blue: concept, design
- Yellow: manufacturing, testing
- Red: integration tests and full demonstration
- Green: research via CIP (selected)

Key:
- PDR: Preliminary Design Review
- CDR: Critical Design Review
- FFR: Flight Readiness Review
- TDH: Tie Down Helicopter
- EPGDS: Electrical Power Generation Distribution System
- FCS: Flight Control System
- ECS: Environmental Control System
- PGGB: Propeller Gear Box
Task 1.5.1 Nacelle Design and Validation

This task will include detail design activities of the engine nacelle, comprising air intake with integral de-icing provisions as well as engine air particle separation for operation in adverse environments; the engines exhaust system, and all associated installations to control and monitor the systems installed in the nacelle. Special attention will be needed for optimization of external (nacelle) and internal (air intake, exhaust and nacelle venting) aerodynamics, building on the previous research performed under Clean Sky GRC2 to support the design of an efficient and flyable installation through wind tunnel testing and simulations. Integration of auxiliary systems (fire detection and suppression, as well as the interfaces with the drivetrain and associated systems) will be covered in this task.

Main deliverables: nacelle structural and installation configuration drawings, physical components and test reports, scale model for wind tunnel testing.

TRL (system level) progress within the task: from 3 to 5

Task 1.5.2 Fuel System Design and Integration

This task will include detail design activities of the fuel system, including refuelling, storage, measurement, transfer, inerting and emergency dump. The unique architecture of the tiltrotor wing will require advanced technology for efficient design of storage provisions meeting safety requirements for crash and lightning protection, while precise measurement in various operating conditions (helicopter and airplane mode) and safe transfer between moving parts will need to be addressed with dedicated research activities. A dedicated test rig will be required for fuel system functional development under all aircraft flight attitudes.

Main deliverables: fuel system description and component detail drawings, physical components and test reports, test rig.

TRL (system level) progress within the task: from 3 to 5.

Task 1.5.3 Engine Control System Integration

This task will include integration activities of the engine control in the flight control system of the vehicle to provide efficient and precise thrust/power response throughout all flight phases. This will be a major challenge and will require the use of dedicated simulation tools and test rigs.

Main deliverables: engine control system and component detail specifications, physical components, associated software and test reports, test rigs.

TRL (system level) progress within the task: from 2 to 5.
8.6.11 Systems and Equipments – WP1.6

This WP will cover the design, development and testing of the following systems:

- Electrical power generation and distribution system (EPGDS)
- Flight control system (FCS), to include flight control computers and software, actuators and sensors.
- Pressurization and environmental control system.
- Ice protection system.

Activities (design, manufacturing, validation) are mainly conducted at sub-system and equipment level, while trade-off studies and validation at aircraft system level are done in “WP1.1 – System Integration”. The estimated budget is 43.0 M€.

Activities related to the design, development, testing and integration of an advanced landing gear system including electromechanical actuation, steering and braking, active damping and autonomous taxing capability will be developed under a separate work package under the Systems ITD and are detailed in that section.
Demonstrator, technologies, links to *Clean Sky 2* pillars, contributors and ROM budget are as follows:

<table>
<thead>
<tr>
<th>Demonstrator</th>
<th>Technology</th>
<th>Greening</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Complete by</th>
<th>Main Actors</th>
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<tr>
<td>D10:</td>
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<td>Intelligent Electrical Power System And Ancillary/ Auxiliary Components</td>
<td>High-speed Brushless generators</td>
<td>Low drag design</td>
<td>Optimal operating Procedures in both airplane and helicopter mode (operations at high altitude)</td>
<td>2018/2019</td>
<td>AW + systems suppliers and partners</td>
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<tr>
<td></td>
<td>Solid state Power conversion and Switching units</td>
<td>Low cost design</td>
<td>High standards on Safety (crashworthiness) and operational flexibility (icing conditions)</td>
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<td></td>
<td>Advanced energy management architectures</td>
<td>High standards on Safety and operational flexibility (icing conditions)</td>
<td>Reduced environmental impact</td>
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<td></td>
<td>Smart actuation Systems</td>
<td>Advanced sensors and Inceptors</td>
<td>High efficiency, Productivity</td>
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<td>D11: Flight Control &amp; Actuation Systems And Components</td>
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WP1.6 structure will be as follows:

![Diagram](image)

Figure 8.10 WP1.6 Structure
Programme plan for WP1.6 is as follows:
**Task 1.6.1 EPGDS (Electrical Power Generation and Distribution System) Components Design, Manufacturing and Testing**

Engineering activities of modelling, design and analysis dealing with detail design of generators (Engine, transmission or APU mounted, as required), control units, switching and accumulation systems to address safety requirements with weight efficiency aimed at enabling NextGenCTR CO$_2$/noise emission reduction targets are addressed in this task. System integration activities to account for all power user systems will be part of this task as well.

R&T will focus on the design of an optimal system where use of power transmission by electrical means will minimize weight and maximize energy efficiency of the connected systems (actuation, de-icing and pressurization), reducing aircraft empty weight and optimizing energy usage throughout the flight spectrum. The reduced empty weight and power off-take from the engines will bring lower fuel burn and consequently lower CO$_2$ emissions, as well as lower direct operating costs (DOC). This technology stream will build on know-how developed in previous EU funded programs and strengthen the developed technology for applications in the rotorcraft field, dominated by even more extreme efficiency requirements. The system will be designed around a main high voltage distribution system leveraging recent advancements in the development of power electronic components. Local downconversion of voltage levels will be performed to support specific loads (e.g. avionics) thereby minimizing the weight and complexity of the power wiring harnesses. Topological optimization of component placement and wiring routing will contribute to the reduction of the overall mass of the system. Overall aircraft models simulating energy usage across systems and in different flight phases shall be developed and used to optimize system architecture, requirements and operation.

Design, validation and testing at component level will be part of this task. EPGDS most innovative components (high speed brushless generators with integral cooling for tilting operations, solid state power conversion and switching units, etc.) will be tested on dedicated benches to support TDH operation and subsequent flight clearance. A representative ground-based electrical rig shall be developed to perform testing of individual components and complete system performance verification for flight clearance.

Main deliverables: power generation system description and components, electrical test rigs.

TRL (system level) progress within the task: from 3 to 6.

**Task 1.6.2 FCS (Flight Control System) Components Design, Manufacturing and Testing**

Engineering activities of modelling and analysis dealing with detail design of Flight Control Computers (FCC), associated software, sensors and actuators to provide advanced flight handling features, address weight efficiency with high safety standards (e.g., flight envelope protection), and enabling NextGenCTR CO$_2$/noise emission reduction targets are addressed in this task.

R&T activities in this task will cover the design of an optimal system capable of providing adequate safety and control while providing the aircraft with the ability to perform the manoeuvres required for the advanced flight path trajectories designed for minimization of acoustic and environmental impact during take-off and landing.
The FCS most innovative components (flight control computers, smart actuators, advanced sensors and inceptor systems) will be tested on dedicated benches to support TDH operation and subsequent flight clearance. A representative system integration rig shall be developed to perform testing of individual components, develop and validate software and complete system performance verification for flight clearance.

Main deliverables: flight control system architecture definition, components (hardware/software), actuators, system integration rig.

TRL (system level) progress within the task: from 3 to 5

**Task 1.6.3 Pressurization and ECS (Environmental Control System) Components Design, Manufacturing and Testing**

The tiltrotor operates at altitudes where pressurization is necessary to support passenger comfort. Traditional systems on aircraft (airplane) rely on bleed air taken from the engine compressors to pressurize the fuselage and operate the air conditioning system. This technology has significant impact on the fuel efficiency of the aircraft. Additionally, transferring hot, high pressure air from the engines, when located in the wingtip mounted nacelles as in a tiltrotor, to the fuselage poses significant technical and safety challenges. To address this problem, a lightweight, reliable, efficient electrical pressurization and air conditioning system is considered an enabler for improvements on fuel consumption and operating costs, while providing the flexibility of unrestricted flight at altitudes unaffected by major weather phenomena and in extreme environmental conditions.

Engineering activities of modelling and analysis dealing with detail design of electric compressors, heat exchangers, control systems, associated software, sensors and actuators to meet safety requirements with weight efficiency are addressed in this task.

The electrical pressurization and air conditioning system components will be tested on dedicated benches to support TDH operation and subsequent flight clearance.

Main deliverables: environmental control system architecture, physical components and system tests.
TRL (system level) progress within the task: from 2 to 6

**Task 1.6.4 Anti-/De-icing Advanced Technologies and Systems (via CfP)**

In order to provide all-weather capability and safe operation in icing conditions upon take-off and landing, as well as in cruise, a complete de-icing and anti-icing system will be necessary. Due to the many moving surfaces (proprotor blades, hubs and spinners; leading edges of fixed and tilting wings and of tail surfaces; interface areas of tilting wing to nacelle and tilting wing to fixed wing) innovative solutions for thermal heating and control of the required areas must be developed to provide a lightweight, reliable, efficient electrical de-icing and anti-icing system with performance far in excess of the current state of the art. Effective system integration will provide improvements on fuel consumption and operating costs, while providing the flexibility of unrestricted flight at altitudes unaffected by major weather phenomena and in extreme environmental conditions.
Engineering activities of modelling and analysis dealing with detail design of heating units, power control systems, associated software and sensors to meet safety requirements with weight efficiency are addressed in this task. Anti-/de-icing components will be tested on dedicated benches to validate solutions studied.

Main deliverables: Anti-/de-icing system description and physical components, test results.

It is planned to cover this aspect launching a Call for Partners.
TRL (system level) progress within the task: from 2 to 5.

8.6.12 Technology Evaluator Interface – WP1.7

Building upon the experience from the Clean Sky Green Rotorcraft Interface with the Technology Evaluator (GRC7), NextGenCTR will establish this work package (WP1.7) within Clean Sky 2 to be able to further develop specific methodologies and assessments applicable to tiltrotor technology.

Therefore activities will address topics regarding tiltrotor technology assessment and provide support to the progress monitoring of the attainment of NextGenCTR objectives.

Key Performance Indicators and other suitable metrics will be established to best assess the progress towards the objectives within the NextGenCTR programme. Vital performance and mission analyses will be performed at the mission level internally in order to be able to substantiate and feed into further assessments to be performed in the Clean Sky 2 TE Impact and Technology Evaluator.

It is expected that this WP will operate within the PHOENIX platform further developing the existing tiltrotor numerical model, adapting it to the new aircraft configuration and to the innovative integrated technologies in order to identify its effect on the environment in terms of gas emission and noise footprint. This WP will assess tiltrotor environmental impact at mission level.

The tiltrotor model will then be delivered to the Clean Sky 2 Technology Evaluator for evaluation of local airport level and global level. The assessment will be conducted not only against the pre-selected environmental objectives but also in regard of transport productivity, time efficiency and ability to operate in confined spaces, as compared to conventional helicopters.
Programme plan for WP7 is as follows:

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- Red: integration tests and full demonstration
- Gray: research via CIP (selected)

- PDR: Preliminary Design Review
- EPDS: Electrical Power Generation Distribution System
- CDR: Critical Design Review
- FCS: Flight Control System
- FRR: Flight Readiness Review
- ECS: Environmental Control System
- TDH: Tie-Down Helicopter
- PGB: Propeller Gear Box
- TRL: Technology Readiness Level
- CIP: Call for Proposal
- RTR: Risk Registration Tool
- RTO: Risk Tracking Office
- ATR: Aeronautics Technology Roadmap
8.7 Compound Rotorcraft Demonstration (LifeRCraft) - WP2

8.7.1 Going beyond Clean Sky

This demonstration project dubbed LifeRCraft\(^{16}\) takes advantage of benefits provided by Clean Sky technologies in order to mature the compound rotorcraft configuration and pave the way for the development of future products fulfilling expectations in terms of door-to-door mobility, protection of the environment and citizens’ wellbeing better than conventional helicopters.

The demonstration configuration embodies the architecture described in Patent FR07-03615 with high-mounted wings which accommodate the transmission shafts driving two tip propellers. It features an airplane-like tail. No tail rotor is needed as the differential propeller pitch ensures main rotor torque balance and aircraft yaw control in hover and low speed.

The project will leverage the own industry background from the X\(^3\) experimental aircraft with the integration on the demonstrator of the most mature and promising systems developed individually within Clean Sky up to TRL5 or 6, as outlined here after.

I. Innovative Blades (CS-GRC1 project)

A set of 3D-optimized rotor blades specified for a conventional helicopter are designed and demonstrated in GRC1. Assuming the results will confirm TRL 5 maturity early 2016, the same optimization approach and tools will be implemented by the partners to optimize the main rotor blades for the LifeRCraft demonstrator, with specifications adapted its flight domain i.e. multipoint optimization taking as objectives both high speed-low lift and hover-high lift points. The same tools will be used for propeller blades optimization taking as objectives both propulsive efficiency and yaw control effectiveness at low speed. Reduction of rotor and propeller noise is part of the blade design exercise as it is the case for helicopters in Clean Sky.

II. Reduction of Airframe Drag (CS-GRC2 project)

The drag of helicopter aft body area (rear access doors) is reduced with careful re-design, fairings and flow control devices. The main rotor pylon, hub cap, blades sleeves are streamlined using smart fairings. These technologies will be transposed to the LifeRCraft airframe with much larger benefits at high speed than for a conventional helicopter. The technologies addressing aerodynamic efficiency of engine integration i.e. engine air intake loss reduction and muffling will reach TRL6 in the period 2014-16 and will find their application on the compound rotorcraft as well as on helicopters due to similarity of engine installation constraints. Direct benefits are expected on fuel consumption, CO\(_2\) emission and noise.

III. Innovative electrical systems (CS-GRC3, -SGO2.3, -EDS projects)

These projects are coordinated and jointly address the integration of high voltage network, energy recovery & storage, electrical actuation into an overall architecture designed for weight and on-board energy savings. Comprehensive system tests will demonstrate TRL5 on a ground Electrical Test Bench in 2015. The LifeRCraft

\(^{16}\) LifeRCraft = Low Impact, Fast & Efficient RotorCraft.
demonstrator will embark a new electrical generation system inspired by Clean Sky architecture and equipment e.g. with 270 VDC network in order to reduce the weight of power buses and reduce power off-takes allowing engines to operate at best efficiency. DC voltage is indeed mandatory on a compound rotorcraft with variable RPM leading to variable frequency, which AC-supplied equipment cannot tolerate.

IV. Eco-Design (CS-EDA, -GRC6 projects)

For composite structures, usage of thermoplastics and low energy low waste production processes (e.g. out of autoclave curing for thermosets) and repair processes for life extension are developed. The replacement of some metallic structures by hybrid structures or full composite ones to save weight on the LifeRCraft (wing, tail unit) can be envisaged with significant advantages for weight reduction hence fuel burn reduction and a subsequent net benefit for the environment. Some new mechanical parts i.e. Propeller Gear Boxes built from metallic materials will be protected from corrosion using the chrome-free and cadmium-free surface treatments that are successfully experimented in Clean Sky (TRL5 in 2015), helping to comply with the REACH regulation. Improvement of the aircraft life cycle will be quantified using the LCA tools selected and deployed in Clean Sky, with results feeding the Technology Evaluator.

V. Neighbourly flying (CS-GRC5 project)

Helicopter specific take-off and landing procedures are defined with dedicated flight guidance systems, both for VFR and IFR operations (SESAR-compliant). These procedures will reduce the noise footprint by as much as 50% thanks to avoidance of the critical flight conditions known as Blade-Vortex Interaction. TRL5 maturity will be reached in 2013 and 2014 with demonstrations performed in segregated air space and TRL6 in 2015, in operational ATM conditions. Similar noise abatement procedures using the guidance systems will be derived for the LifeRCraft configuration taking advantage of its additional degrees of freedom: thrust split between propellers and rotor and additional control surfaces allowing a suitable management of attitude compatible with higher take-off and approach slopes.

VI. General remarks concerning up-take of Clean Sky technologies on a new rotorcraft configuration

It is important to notice that the uptake of a Clean Sky technology/system by the LifeRCraft project will change more or less significantly the external constraints and the specifications e.g. mechanical and electrical interfaces, size, weight, sensors, deflections, airloads, etc due the different vehicle configuration and size and power and speed. Consequently the TRL level of each technology/system upon start of LifeRCraft integration will generally be lower than reached within Clean Sky at that point in time. For instance, the design of drag reduction devices suited for light helicopter bluff aft end (clam shell doors) having reached TRL6 in Clean Sky will have to be reconsidered in the context of the LifeRCraft which features a much slimmer fuselage/tail junction and possibly, lateral doors. Integration will therefore start at TRL3-4 only, despite the fact that the same computational and experimental tools can be used with confidence. On the other hand, the approach flight profiles designed for conventional helicopters are expected to remain valid for a compound rotorcraft, even though the airspeed schedule, propeller-rotor thrust split and guidance system software will be specific. Upon start of LifeRCraft integration, the maturity could be TRL5 instead of TRL6 for helicopters.
8.7.2 Specific challenges to be tackled by the LifeRCraft Demo

The compound rotorcraft architecture offers a combination of flight capabilities and versatility that uniquely caters for progress toward the FlightPath2050 mobility objective (4-hour maximum door-to-door journey for 90% of European travellers). Moreover, it can accomplish that progress in a resource-efficient and environment-friendly way, with enhanced safety and security for the EU citizens. Indeed, the large rotor ensures a superior load capability and agility in vertical take-off and landing, operating neighbourly without need for costly ground infrastructure and with moderate downwash and no ground erosion. Technologies to reduce the acoustic footprint as developed in Clean Sky for helicopters e.g. dual speed rotor and optimized flight path are either readily applicable or can be adapted to compound rotorcraft. In forward flight, the auxiliary propulsion and lifting wing provide a lift-to-drag ratio much improved as compared to a conventional helicopter, allowing for a smooth ride, flat cabin attitude and reduced fuel consumption. The compound rotorcraft can cruise farther and at much higher speed than a helicopter of the same weight and power level. When employed for search and rescue missions or medical evacuation where human life is at stake and minutes are critical, a compound rotorcraft can dash straight to the accident site wherever it can be (high mountain, off-shore, city or highway) and hoist or embark wounded/sick individuals through large access doors and fly back to the relevant hospital at speeds higher than 400 km/h.

High speed rotorcraft in general and compound rotorcraft in particular are not expected to replace conventional helicopters in roles for which they perfectly meet the demand but they will open new market slots for transport missions that neither helicopters nor fixed-wing aircraft can perform. Assuming EU industry can master and develop the compound rotorcraft configuration before its foreign competitors (e.g. UTC’s X2 counter-rotating compound concept), the gained competitiveness will allow to maintain and further increase the EU market share up to 60% of the whole civil/parapublic rotorcraft sector; failure to secure technology leadership in this new high speed rotorcraft segment will result in a steady decline of EU industrial competitiveness with a market share falling below 40% within the next decade.

To date, the know-how and technology maturity for compound rotorcraft in Europe appears by far insufficient for industry to accept the risk of a commercial development. The feasibility and speed capability of the aerodynamic configuration was successfully explored by Eurocopter in the recent years thanks to the X³ low scale test bed. X³ is the only experimental compound rotorcraft ever flown in Europe since the Fairey Rotodyne in the 1950’s. This experimental rotorcraft combines existing components borrowed from miscellaneous helicopter types. It is significantly over-powered in order to offset excess aerodynamic drag and empty weight, which result from conventional structural design and construction techniques used for the sake of expeditious realisation. The X³ first flew on 6 September 2010 and recorded a level flight speed of 255 Kt on 7 June 2013. Enough experience has been accumulated to confirm the concept basic soundness with flight domain extension.

On the other hand, this rather crude, heavy and over-powered test bed makes no provision for transport productivity; with a high fuel consumption and quite limited payload-range capability. Its high noise level stems from usage of existing dynamic components operating beyond their design domain. There is no possibility at this stage to assess the commercial potential based on such an experimental vehicle dedicated solely to flight envelope exploration. The technology maturity of the overall compound rotorcraft concept remains quite
low, with TRL ranging from 4 to 5, owing to small size and lack of any consideration neither for realistic transport capabilities such as payload, range, fuel efficiency, cabin access, nor for operational requirements, gas emission, community noise, cabin noise, structural weight, reliability, production methods, maintainability or cost.

8.7.3 The role of the LifeRCraft Demo

Innovative construction technologies and an optimized design approach tailored for such a configuration have now to be implemented in order to demonstrate the technical and industrial capacity to deliver the needed level of operational performance with affordable and proportionate industrial means and to bridge the gap that currently prevents launching development activities.

The specific role of the LifeRCraft demonstration consists in:

- Maturing further the novel compound rotorcraft architecture aiming to fulfil technical objectives of transport capacity and productivity, mission functionality, environmental protection and acceptability by the population;
- Inserting and adapting innovative technologies individually matured in Clean Sky up to TRL 5-6 that will allow to reach these maturation objectives at integrated aircraft level;
- Federating efforts of the European value chain toward a challenging and game-changing aeronautical project, addressing additional domains and technical aspects not previously considered for rotorcraft within Clean Sky such as airframe structure optimization or certification rules for compound rotorcraft, thereby involving new partners not familiar with rotorcraft;
- Providing a flying platform which will be available after Clean Sky 2 completion for insertion and demonstration of technologies which are being developed concurrently at a lower maturity level in different frameworks, targeting longer term ACARE objectives (horizon 2035).

The project aims at demonstrating that this compound rotorcraft configuration implementing and combining cutting-edge technologies as from Clean Sky opens up new mobility roles that neither conventional helicopters nor fixed wing aircraft can currently cover in a way sustainable for both the operators and the industry. This exploitation potential is expected to secure early Clean Sky benefits in terms of European leadership and value creation.

A new, large scale flightworthy demonstrator embodying the compound rotorcraft architecture will be designed, integrated and flight tested. This demonstrator will allow substantiating the Technology Readiness Level 6 at whole aircraft level prior year 2020. The project is based on:

- identified mobility requirements;
- environmental protection objectives;
- lessons learnt from earlier experimentation with the compound rotorcraft architecture concept;
- technology progress achieved for rotorcraft subsystems on one side through participation to Clean Sky projects and other research activities at EU or local level;

The new LifeRCraft demonstrator will incorporate the following essential features:

- A fuselage hosting a versatile cabin that can accommodate usage for either passenger transport or Search & Rescue mission (including typical equipment e.g. rescue hoist, wide access door) or Emergency Medical Service (cabin configuration with stretchers and medical personnel and equipment);
- A main rotor ensuring vertical flight capacity;
- A fixed wing off-loading the rotor in high speed flight;
- A tail unit with vertical and horizontal stabilizing surfaces and control surfaces, but no tail rotor;
- Two propellers located at the wing tips with differential and collective pitch control ensuring both yaw control in the low speed envelope and thrust control in the full flight envelope;
- A drive train connecting the turboshaft engines with the main rotor and propellers, with RPM variation for tip Mach number control through the flight envelope;
- An automatic flight control system taking advantage of additional control degrees of freedom in order to trim the airframe longitudinal and lateral attitude for best aerodynamic efficiency and minimal dynamic loads on rotating components in the full flight domain.

Demonstrating TRL6 maturity for this configuration featuring the excellent vertical flight performance of a conventional helicopter while radically improving the cruise speed, transport effectiveness and fuel efficiency raises a whole range of technical challenges for the design team and for whole supply chain. In a nutshell, they boil down to the few following ones:
- Maintaining a high hovering efficiency (Figure of Merit), minimizing rotor-wing interaction;
- Maintaining a low empty weight fraction, in spite of the additional components such as wing and propellers;
- Maximizing the airframe Lift-to-Drag ratio, in spite of the rotor pylon and moderate wing span;
- Optimizing propeller design for both propulsive efficiency and yaw control function;
- Maintaining fair rotor performance at high speed, with reduced lift and RPM;
- Designing a light, efficient and reliable mechanical drive system, in spite of its increased complexity;
- Keeping the production and operating costs of this more complex rotorcraft within reasonable bounds as compared to a conventional helicopter.

### 8.7.4 High level demonstrator objectives

#### Societal challenges: mobility & safer society

In order to respond and contribute significantly to the Horizon2020 mobility challenge, the LifeRCraft demonstrator targets the following specific mission capabilities:

- Gate-to-gate passenger transport over 550 km completed in less than 90 minutes;
- Rescue & Emergency Evacuation over 400 km, from rescue center to any accident location (sea, mountain, road or island) in less than 60 min, then landing at an unprepared spot or hovering and hoisting victims, then bringing them back to an hospital (same distance forth and back).

Compliance with the first of these mission objectives will show that journeys between distant business districts can be performed very efficiently without resorting to time consuming multi-modal transport and avoiding congested city centres, ground infrastructure and conventional airports.
Compliance with the second of these mission objectives will demonstrate the dramatic extension of the area that can be covered within the “golden hour” by a rescue compound rotorcraft as compared to conventional helicopters (doubling that area), thus increasing significantly the probability of survival for victims after accidents or disaster at sea or on land.

**Environmental objectives**

In line with *Clean Sky 2* general objectives, the demonstrator shall also meet specific targets in terms of environmental protection:

- Noise level less than conventional helicopters, target: less than 96 EPNdB (averaged over the three flight cases: take-off, fly-over and approach)
- Acoustic footprint 20% smaller than conventional helicopters, thanks to specific noise abatement procedures;
- Fuel consumption and CO$_2$ emission per kilometre 10 to 12% less than conventional helicopters.

Comparative figures are based on the latest helicopter types of the same weight class commercially available in 2014.

The project will show that the Eco-Design approach implemented for fixed-wing aircraft and helicopters in *Clean Sky* can be further deployed for the compound rotorcraft configuration, including use of substitutes or new materials, eco-efficient production methods, and full life cycle optimization.

**Technical performance goals**

These high level objectives translate into performance goals at full aircraft level:

- Peak fineness $L/D_e$: 20% better than for a conventional helicopter of same weight class;
- empty weight fraction: less than 63%;
- Maximum operational cruise speed: 220 Kts.

The fineness $L/D_e$ or equivalent Lift-to-Drag ratio is defined as for a turboprop aircraft, with flight weight $M_g$, level flight velocity $V$, and shaft power at engine interface $P$:

$$L/D_e = \frac{M_g \cdot V}{P}$$

The empty weight fraction is the ratio between the empty weight and the Max Take-Off Weight.
The synoptic here above indicates how individual subsystem performance specifications impact the overall performance mission.

**Competitiveness & industrial leadership objectives**

The full success in fulfilling the above mentioned demonstration objectives will not suffice to secure industrial implementation and market up-take of this novel compound rotorcraft configuration unless/until favorable economic conditions can be created such that operational exploitation will be attractive enough for private owners and affordable for public service missions.

The transport productivity which grows in a linear fashion with the average mission speed will obviously be very favourably impacted by the intrinsic speed capability of this compound rotorcraft concept, typically 50% higher than that of a state-of-the-art helicopter. However one has to ensure that the evolution of other factors in the transport productivity such as the Direct Operating Cost (DOC) will not offset this benefit. As the speed gain is obtained thanks to a novel combination of evolutionary subsystems derived either from helicopter or from airplane technology, it is expected that the cost per flight hour will increase in a much smaller proportion than the performance so that, overall, the total operating cost for a given mission can decrease significantly in comparison to conventional helicopters. Actual results of the LifeRCAft demonstration will enable to quantify the potential transport productivity gain for future products, taking into account technical successes and encountered difficulties.
The full life cycle cost critically depends not only on DOC but also on the aircraft production cost. This production cost is determined by the technologies and construction processes and tools that are implemented by the supply chain. A range of innovative technologies are considered in order to minimize weight e.g. new composite materials and construction methods; however some of them might have an unfavourable impact on the cost of either materials or manpower or production investment (moulds, robots) unless special care and attention is devoted to that aspect. Consequently trade-off studies will be necessary to select among possible alternative technologies the best compromise between operational performance and production cost and operating cost. Each of the numerous subsystems or components having different influence coefficients on the various terms in the performance and life cycle cost equations, the overall problem appears much too complex to be tackled analytically and no specific cost objectives can be fixed beforehand for the demonstrator subsystems.

Considering however this technology demonstration as a unique opportunity to integrate and test advanced solutions, one will generally give precedence to technical performance objectives e.g. weight and drag and noise reduction over cost effectiveness in order to satisfy mission criteria in the first place. Then in parallel, the impact of innovative technologies on cost indices will be assessed. Wherever the cost-to-performance trend would appear excessively unfavorable, a more conventional solution could be preferred as a baseline; this should nonetheless not prevent experimenting innovative solutions at part of this project, possibly limited to laboratory testing unless the risk (either technical, calendar or budgetary) would appear unacceptable. Even more advanced and less mature technologies can be studied in parallel to this project through additional activities.

Giving precedence to technical performance over cost control is supported by the generally accepted rationale stating that industry competitiveness achieved by introducing leading edge technology and innovation is more sustainable and creates high skilled jobs whilst that obtained solely through the reduction of production costs is often associated with externalization of production activity to countries with lower manpower rates and has only a transient positive impact on the economic activity.

Beside cost effectiveness and even more importantly, higher speed means attending victims of accidents occurred in remote locations in the shortest possible time, thereby increasing mission effectiveness with a higher rate of survivals (Search & Rescue, Emergency Medical Service). What is at stake here is meeting the growing citizens’ demand for a safer and healthier life.

As challenging as it may appear, meeting these objectives of transport efficiency, cost effectiveness and mission effectiveness will open up new market slots with significant quantities. This will allow enhancing the European competitiveness and maintaining leadership of the European aeronautical industry supplying the rotorcraft sector.
8.7.5 Setup of the LifeRCraft Demo

The LifeRCraft demonstration project is organized in three groups of mainstream technical work packages, as shown on the upper level Work Breakdown Structure here below.

![Figure 8.12 - LifeRCraft Upper Level WBS](image)
These three work package groups form essential branches of the famous system development “V”.

I. Work package WP2.1

Work package WP2.1 includes all “Project Management & Integration Activities” of technical nature i.e. the left upper layer of the “V”. According usual industry practice, the “Project Management & General Design” activities (WP2.1.1) will be led by a Chief Engineer having functional authority over all project participants for the full project duration. That role is essential to ensure proper work coordination and synchronisation of individual component/technology developments with an overarching vision of system architecture and integration. The Chief Engineer will be supported by a dedicated team in charge of project coordination and specialized teams in charge of tasks concerning the full aircraft system: general architecture; pre-project sizing; mission performance prediction; subsystems interface definition; configuration management, weight & balance, Digital Mock-Up. Most general engineering teams (aeromechanics, aeroacoustics, aerothermics, EMI, icing protection, lightning protection, dynamics and vibration, flight loads and simulation, safety and reliability analysis, airworthiness) will also be involved as the demonstrator differs dramatically from a conventional helicopter and will have to substantiate its airworthiness in order to obtain a civil Permit-to-Fly.

II. Work packages WP2.2 to WP2.12

These work packages contain the activities for design and realisation of all individual components and subsystems i.e. the bottom part of the big “V”. They start with the general specification and draft interfaces issued by WP2.1, then progress through technology section and preliminary design with some modelisation, simulation and some elementary tests; the detailed design is completed between the PDR and the CDR. After the CDR, design is frozen and the components needed for the flight demonstrators and also for some isolated component tests are produced. Along the design phase, all these work packages will feed WP2.1 back with component performance and interface constraints which will help secure the overall design convergence. For each component, specific validation and verification results will support the compliance to specifications and the substantiation of airworthiness and life duration.

The components/subsystems not requiring a design specific to the compound rotorcraft configuration and which bring little/no technology improvement potential with respect to the project objectives are taken from current helicopter or aircraft inventories (COTS), with as little adaptation as required for matching the demonstrator interfaces and operating conditions: engines, main rotor hub, part of the Main Gear Box, monitoring system, avionic suite. Efforts will be concentrated on new specific components and those for which introduction of innovative features or particular tailoring will bring sizable benefits that will enable matching the demonstration objectives. Particularly so for: airframe and cabin, propellers, rotor blades and hub & pylon fairing, new parts of the drive system, landing system, actuators and FCS, new guidance mode for noise abatement implemented in the FMS and AFCS.

As far as possible, for subsystems which incorporate a high degree of innovation and represent a substantial development risk for the whole project, a mature back-up solution will also be made available in order to mitigate
that risk. For instance, a set of conventional helicopter blades will be prepared to substitute the specifically optimized blades in case the latter would not behave satisfactorily during flight trials.

III. Work package WP2.13

Work package WP2.13 collects part of the integration activities, including assembly and testing of whole rotorcraft articles, for validation, verification and final in-flight demonstration: the upper right part of the big “V”.

Two major integration test articles will be assembled and tested: the rotor system rig integrating the rotor and the propellers and the final flight demonstrator itself.

WP2.13 will start from the delivery of all physical components and subsystems, each of them having reached the maturity level TRL4 (or more) through dedicated simulation and isolated tests. Following successful completion of ground tests with the electrical and flight control systems (WPs 2.8 and 2.12), the mechanical drive system rig (WP 2.6), the rotor system rig and the shake test with the flight demonstrator, it is expected that conditions for passing TRL5 will be satisfied for most components and subsystems. Finally, the flight test campaign and demonstration will allow assessing the maturity of all embarked components and subsystems at TRL6.

In order to reach TRL6, the following success criteria will be addressed and assessed:

- **Technical criteria**: Availability of specifications for overall demonstrator and all subsystems and their consistency with key mission specifications; operating conditions known and described; technologies proven in a relevant environment i.e. essentially in flight; interface requirements fully defined and final; main failure modes and their effects verified e.g. during integration tests; certificability established with needed steps estimated;

- **Engineering management criteria**: engineering feasibility thoroughly demonstrated; demonstrated capability to manage the development process i.e. technical risk management capability; specific IPR identified and agreed between partners; Validation and Verification Plan available; SWOT analysis conclusive;

- **Manufacturing capability criteria**: assembly process feasible according to manufacturing specs; configuration control initiated; exploitation capacity of partners and supply chain checked; conditions for quality insurance available; critical manufacturing processes stabilized; availability of an estimate for production means.

8.7.6 Partnerships

Under the OEM coordination, the project will involve a full range of core partners and partners selected on the basis of their skills and track record best suited for specific activities: simulation specialists and research labs for advanced technology developments and subsystem testing, aeronautical supply chain (including innovative SMEs) for detailed design and production of demonstrator components. Many research activities initiated in Clean Sky GRC-ITD or earlier collaborative projects dealing with rotorcraft will be extended for technology adaptation to the compound rotorcraft configuration. It is consequently expected that most of the partners and associates from many EU countries with substantial relevant background will apply again and be selected for participation in this project. Furthermore, new skills are now needed i.e. for composite airframe structure, landing system or propellers; consequently more participants representing an even broader variety of countries are expected to join the project and contribute to its success. Some details concerning required skills and profile of core partners and partners are shown in the work plan table.

The integration of some COTS within components or the manufacturing of some new parts using only conventional production process does not generate significant research added value but is nonetheless necessary in this large scale integration project. Consequently it is unlikely that manufacturers of these COTS or parts will...
invest their own funds and participate as partners in the project. The same could be happen with some needed services i.e. for ground test or wind tunnel facilities. As a consequence, the project leader or core partners may need to procure the parts or subcontract the services under commercial conditions, selecting the suppliers after an open competition in order to benefit from best value for money. The Clean Sky JU is expected to manage Calls for Tenders that will facilitate involvement of suppliers in due time for seamless project progress. Call for Tenders will be particularly attractive for SMEs that can work efficiently but lack own funds to participate as risk sharing partners.

### 8.7.7 Project Master Schedule

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8.7.8 Major deliverables

The LifeRCraft project will deliver the following main results:

- An extensive flight campaign with a large scale demonstrator (TRL6 at full system level), substantiating the feasibility, efficiency and viability of a fast rotorcraft implementing a unique compound rotorcraft architecture and responding successfully and simultaneously to the high level objectives:
  - Environmental compatibility (including reduction of GHG emissions, noise level and footprint, and life cycle improvement);
  - Enhanced door-to-door mobility (range, speed, fuel efficiency) beyond current helicopter limits, including superior capabilities for search and rescue and emergency operation;
  - Acceptable additional complexity, weight and cost penalties which would not hinder the further development and deployment of commercial products based on this rotorcraft configuration.
- Components and subsystems specific to this rotorcraft demonstrator and associated ground test articles which implement an innovative concept or design or specific optimization in order to meet the objectives e.g. airframe and cabin, landing gear, drive system, propellers, rotor blades, electrical actuators and electrical system, FCS, etc. such design objectives allowing to reduce and meet specific performance targets such as noise at source, weight, or/and aerodynamic efficiency;
- A set of key performance indicators allowing to measure progress against the plan in terms of technical maturity, risk management, earned value vs budget, IPR protection and dissemination of results.

8.7.9 Interactions within the Rotorcraft IADP; Interactions with ITDs

The JU executive team will monitor both fast rotorcraft projects conducted in the Rotorcraft IADP and will be in position to compare progress with the support of the Technology/Impact Evaluator. It will ensure feedback and organize joint reviews to secure maximum exploitation potential and impact for the EU society and global market penetration of EU industry with the outcome of both demonstration projects, as the combination of two advanced rotorcraft architecture will minimises the overall risk of not fully achieving the objectives.

The LifeRCraft demonstration strongly depends on the Airframe ITD to develop and timely produce critical and high performance airframe flightworthy components namely the wing and the tail unit. Requirements and interfaces will be specified in several steps jointly by the LifeRCraft Chief Engineer and the leader of Airframe ITD WP0.3.B.2. According to the schedule, the specifications and interfaces will be reviewed by September 2015 (PDR) and frozen early 2017 (CDR). The delivery of components for demonstrator assembly is required for end 2017.

Collaboration of the present project is also expected to take place with Small Aircraft Transport leaders and partners involved in Airframe ITD, WP HVE-B1 “Next generation optimized wing box”. There might be indeed some commonality in the requirements owing similar size, lift, airspeed and the need for minimize weight with a composite structures.

Following joint Clean Sky activities with all aircraft manufacturers and research laboratories in the Eco-Design ITD, collaboration will be extended in Clean Sky 2 between LifeRCraft WP2.2 (Airframe Structure), WP2.5 (Drive System) and Airframe ITD WP HVE-B3.6 “New materials & manufacturing”, sharing some information on new
materials and processes test results on coupons and small parts for the mutual benefit of all participants. Similarly, the same parties in Clean Sky 2 intend to collaborate with the participants in Airframe ITD HPE A-3.5 “Eco Design”, sharing data for implementation of the Life Cycle Assessment approach and further enrichment the common data base set up in Clean Sky.

The LifeRCraft project will deliver in WP2.1.5 the conceptual model required by the Impact Evaluator for assessment of all impacts on the environment, on mobility and transport productivity, according to precise criteria to be defined. The Impact Evaluator is expected to use this model at airport and global transport system level whilst WP2.1.5 will conduct self-evaluation at mission level. However, permanent exchanges will take place between Impact Evaluator and the LifeRCraft project, to secure consistency of assumptions and conclusions.

The improvement identified [CP26] for Turboshaft engines inside Clean Sky 1 and Engine ITD (small size HP Cores) could be included in the Technical evaluation of the performance of a future product based on the LifeRCraft high speed rotorcraft. For the design of the electrical generation of the LifeRCraft High Speed Rotorcraft, it will be investigated the possibility to use components developed within Clean Sky 1 or within the Systems ITD for the Electrical Chain (WPS).
8.7.10 LifeRCraft Project Management & Integration Activities – WP2.1

I. Relevance and technical objectives

The project management and integration activities drives the demonstration at complete rotorcraft level along the full duration from the prefeasibility and specification until the flight testing phase. These cross-cutting activities ensure technical consistency and timeliness of all other technology and subsystem development activities. Trade-off or resolution of technical issues to accommodate specific constraints and opportunities in different technical areas are ensured in WP2.1. The WP2.1 leader is ultimately responsible of project achievements and shortcomings against all high level demonstrator objectives (transport efficiency, environmental protection) to be substantiated at the highest possible maturity level.

II. Setup and activities

This WP includes all “Project Management & Integration Activities” of technical nature. It consists of the following 2nd level work packages:

a. Project Management & General Design - WP 2.1.1

WP 2.1.1 is led by the Chief Engineer having functional authority over all project participants throughout the full project duration. That role is essential to ensure proper work coordination and synchronisation of individual component/technology developments with an overarching vision of system architecture and integration. The Chief Engineer is supported by a dedicated team in charge of project coordination and several other teams tasked with the following cross-cutting roles: general rotorcraft architecture and sizing, mission performance prediction, configuration management, Digital Mock-Up set-up, weight & balance book keeping. This team is concerned with defining interfaces and issuing specifications that are to be kept consistent across all internal departments, partners and suppliers who participate in the design and realisation and verification activities. Other teams perform specific cross-cutting tasks in direct support to the Chief Engineer team: general rotorcraft architecture and sizing, mission performance prediction, subsystem interface definition, configuration management, Digital Mock-Up set-up, weight & balance book keeping. Concurrent progress is permanently monitored and whenever deviations occur with respect to the project plan for any reason (technical mismatch, resources, schedule), the Chief Engineer has to examine the issue and propose a trade-off or a mitigation solution for adoption by concerned parties then to update the plan and specifications accordingly.

b. General Engineering – WP 2.1.2

The expert engineering teams (aeromechanics, aeroacoustics, aerothermics, EMI, icing protection, lightning protection, dynamics and vibration, flight loads and simulation, safety and reliability analysis, airworthiness) need to be deeply involved in the LifeRCraft design and optimization as the demonstrator differs dramatically from a conventional helicopter and faces challenging technical objectives and will have to substantiate its airworthiness in order to obtain a Permit-to-Fly from EASA. They will remain involved, although with a lower activity level for some of them, during the demonstration tests in order to analyse data, compare with analytical predictions and propose solutions in case of unexpected results. Support of Research Institutes or specialized labs is expected. Collaboration with EASA will first target to determine the regulatory basis for flight worthiness justification of this particular rotorcraft configuration and, at a later stage, to provide evidence of compliance necessary to obtain a Permit-to-Fly for the demonstrator.
c. **Digital Wind Tunnel - WP 2.1.3**

Further to the numerical simulation approach used in CS-GRC1 and GCR2 for conventional helicopters, high fidelity aerodynamic and aeromechanical models addressing the whole LifeRCraft configuration will be exercised over the critical points of the flight in order to assess the interactions between the airframe, the rotor and the propellers. Such interactions have a dramatic impact on the overall aerodynamic performance. In order to select the sizing, positing and shaping of aerodynamic surfaces, the aerodynamic performance has to be evaluated quickly and early in the design process i.e. prior to the Preliminary Design Review (PDR). Further refinement may be necessary after separate design and optimization of aerodynamic components and prior to the Critical Design Review (CDR).

The OEM will seek collaboration with specialized Research Institutes or Universities having developed efficient CFD tool suites and able to generate rapidly accurate aerodynamic grids for complete rotorcraft configurations, to perform RANS calculations and to analyse results over a large number of configurations over the flight domain, possibly including some multipoint optimizations. The first Digital Wind Tunnel exercise has to be completed in less than 12 months. A first Partner activity has already been identified in WP 2.1.7.

d. **Wind Tunnel Testing – WP 2.1.4**

Following the methodology implemented in CS-GRC2, wind tunnel tests will be performed with a down-scaled model with active propellers and a spinning rotor hub so as to confirm performance benefits of numerically optimized configurations and to determine the airframe forces and moments on a wide range of angle of attack and side slip, including some configurations that may not be properly predicted by numerical simulation. A first test campaign will be conducted with the design selected at the PDR along with possibly some alternate design option(s). After detailed design studies of the various components, a second test campaign might be performed in case significant changes have been introduced affecting e.g. fuselage, wing or tail size and shapes.

The OEM will seek collaboration with a Research Centre or laboratory having expertise in the design and construction of down-scaled rotorcraft models with rotating components and internal balances to separate contributions of fixed airframe from rotating components. Flow visualization and measurements in unsteady flow conditions would help understand the physics of separation and operations of passive flow control devices (if any). A first Partner activity has already been identified in WP 2.1.7.

e. **Eco-Design & Life Cycle - WP 2.1.5**

This work package aims at supporting the teams and partners who design the specific subsystems and components (WP2.2 to WP2.12), advising them for the selection of materials and manufacturing processes that provide best performance combined with reduced impact on the environment throughout the aircraft life cycle, in the footsteps of current CS-EDA, EDS and GRC6 projects. Life Cycle data will be collected for the different vehicle components. Such data will feed the Eco-Design assessment and the upscaling process performed in WP0.3 and will allow evaluating progress using the common Life Cycle Assessment tools. This exchange will take place through permanent links with joint tasks in the ITD Airframe HPE A-3.5 and HPE A-B-0.5. The specific impact of compound rotorcraft will be identified as compared to conventional helicopter. Collaboration with laboratories specialized in Life Cycle assessment is expected.

f. **Technology Evaluator for LifeRCraft - WP 2.1.6**
Further to the work performed in CS-GRC7 with the PHOENIX platform, a conceptual compound rotorcraft numerical model will be established to identify effect of the new rotorcraft configuration with its integrated innovative technologies on the environment, in terms of gas emission and noise footprint. This model which extrapolates the LifeRCraft results to future compound rotorcraft products will be assessed at mission level within this work package using tools, baseline, fleet assumptions and assessment criteria defined jointly in the joint WP 0.2. It will further be delivered to the Clean Sky 2 Technology Evaluator for evaluation of local airport level and global level. The assessment will be conducted not only against the pre-selected environmental objectives but also in regard of transport productivity, time efficiency and ability to operate in confined space, as compared to conventional helicopters.

The establishment of the conceptual model required collaboration with an engine manufacturer. It is expected that a research institute or university will perform the assessment work as part of this work package.

g. **Aerodynamic optimization for LifeRCraft - WP 2.1.7**

This WP concerns the Partner topic FRC2.1-1 in connection with WP2.1.3 and 2.1.4.

h. **Cabin active resonator for vibration control - WP 2.1.8**

This WP concerns the Partner topic FRC2.1-2 in connection with WP2.1.2 and 2.11.
III. High level WBS

![High level WBS Diagram]

IV. Added-value versus state-of-the-art

No previous experience exists in the European rotorcraft industry of such a game-changing aircraft configuration being matured through incorporation of innovative individual technologies up to the stage of flight demonstration at a maturity level of TRL6. The successful implementation of WP 2.1 will translate into a cumulated added value from the LifeRCraft project which represents much more than the sum of values added by all individual subsystem developments as it will considerably reduce the risk to be faced by subsequent product development programmes.
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<th>WP L2</th>
<th>TITLE</th>
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<th>Lead Actor &amp; Key Contributors</th>
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<tr>
<td>WP2.1</td>
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<td></td>
<td>LifeRCraft Project Management &amp; Integration Activities</td>
<td>CS GRC</td>
<td>AHG</td>
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<td>2.1.1</td>
<td></td>
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<td>Project Management &amp; General Design</td>
<td>General architecture &amp; sizing optimized for compound R/C specific requirements; mission performance prediction; subsystems interface definition; configuration management, weight &amp; balance, Digital Mock-Up</td>
<td>LifeRCraft specifications matching challenging demonstration objectives (smart mobility, mission productivity, environmental protection)</td>
<td>X² test bed project</td>
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<tr>
<td>2.1.2</td>
<td></td>
<td></td>
<td>General Engineering</td>
<td>Aeromechanics, aeroacoustics, aerothermics, dynamics &amp; vibration, flight loads and overall vehicle simulation, safety analysis &amp; airworthiness (Permit to Fly)</td>
<td>Support to WP2.1.1 for overall sizing, design and optimization; Know-how acquired for rotorcraft with extended flight envelope</td>
<td>NICETRIP IP, X² test bed project</td>
</tr>
<tr>
<td>2.1.3</td>
<td></td>
<td></td>
<td>Digital Wind Tunnel</td>
<td>Full rotorcraft simulation with CFD-CFS coupling, actuator disks and full unsteady calcs, full flight envelope (incl. hover)</td>
<td>Selection of best design variants in support of WP2.1.1 and 2.1.2; Building the digital wind tunnel for rotorcraft with extended flight envelope</td>
<td>NICETRIP IP, CS GRC1, GRC2</td>
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<td>2.1.4</td>
<td></td>
<td></td>
<td>Wind Tunnel Testing</td>
<td>Downscaled model(s) with and w/o active propellers and spinning rotor hub (no blades) Internal balances; flow measurements techniques (PIV)</td>
<td>Validation of selected design variants, complete airframe aero data (6 components, with and w/o prop interference) in support of WP2.1.1 and 2.1.2; Capability for compound R/C downscaled models &amp; extended test envelope</td>
<td>CS GRC2</td>
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<tr>
<td>WP L1</td>
<td>WP L2</td>
<td>TITLE</td>
<td>Technologies / Activities</td>
<td>Results / Added value</td>
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<td>Lead Actor &amp; Key Contributors</td>
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<td>2.1.5</td>
<td>L1</td>
<td>Eco-Design &amp; Life Cycle</td>
<td>Monitoring and advising for the selection of materials and processes in WP2.2 to WP2.12; Supporting internal and external suppliers for collection of Life Cycle data relevant for Fast Rotorcraft.</td>
<td>Data exchange with other OEMs and Fraunhofer Institute enriching the common LCA data base; Assessment of progress in LC improvement and potential impact of fast rotorcraft emergence (links with Airframe ITD HPG5.1 &amp; HAV4.4)</td>
<td>CS EDA, EDS, GRC6</td>
<td>AHG, labs (in liaison with partners in WP2.2 to WP2.12)</td>
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<tr>
<td>2.1.6</td>
<td>L1</td>
<td>Technology Evaluator for LifeRCraft</td>
<td>Rotorcraft metrics; fleet forecast (coordinated with 2GenCTR demo); LifeRCraft conceptual model (perfo, emission, noise); mission simulation and impact assessment at mission level regarding environment, mobility, transport productivity</td>
<td>PHOENIX extension to compound rotorcraft config; Evaluation at mission level; Inputs needed by TE for impacts at Airport and ATS levels</td>
<td>CS GRC7, TE</td>
<td>AHG, engine supplier, Research Institutes</td>
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<tr>
<td>2.1.7</td>
<td>L1</td>
<td>Aerodynamic optimization for LifeRCraft</td>
<td>CFD-CFS coupling, actuator disks and full unsteady calcs, full flight envelope (incl. hover) Downscaled model(s) with and w/o active propellers and spinning rotor hub (no blades) Internal balances; flow measurements techniques (PIV)</td>
<td>Selection and Validation of best design variants, complete airframe aero data Obtain the best performance in cruise flight</td>
<td>Research Institutes or univ. with background on rotorcraft WT models &amp; tests as Partners</td>
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<td>2.1.8</td>
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<td>Cabin active resonator for vibration control</td>
<td>Active resonator operating in a wide frequency range</td>
<td>Reduced Vibration level in cabin</td>
<td>Research Institutes &amp; labs, equipment manufacturers as Partners</td>
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V. Partnerships

As mentioned in the description of WP2.1.2 through WP2.1.6.

VI. Schedule

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8.7.11 Airframe Structure – WP2.2

I. Relevance and technical objectives

The airframe for this new compound rotorcraft architecture is bound to be heavier than that of a conventional helicopter as it needs to withstand higher dynamic pressure and resist bird impacts with higher energy due to high speed. It incorporates a wing not present on helicopter. It must carry flight loads and ground loads in proportion of the higher all-up weight and stronger engines and drive train as compared a helicopter of similar capacity. In order to mitigate consequences and achieve a reasonable empty weight ratio, it is essential to use the best performing construction materials and implement the latest structural concepts and construction techniques in order to minimize weight. On the other hand, one should not neglect essential constraints such as the production recurring cost or the impact of selected techniques on the Life Cycle (life duration, health monitoring, maintenance, reparability).

Requirements for low aerodynamic drag translate into the need to shape the fuselage with a slim cross section and streamlined profile whilst it has to preserve the fundamental helicopter functionalities. This calls for securing easy cabin access for special emergency services such as medical evacuation with stretchers or hoist operation with crew or wounded persons on the hook; such access needs to be protected against any interference with propeller blades or slipstream. The airframe architecture has thus to be reconsidered with a vision quite different from that of conventional helicopter or of fixed wing aircraft. The aerodynamic cleanliness also requires low geometrical tolerances, elimination of gaps and bumps and minimal surface roughness that depart from accepted standards in the helicopter industry.

Compliance with some of the high level technical objectives very much depends on airframe architecture and construction, particularly for those objectives:

- Peak vehicle fineness $L/D_e$: improvement +20% w.r.t. conventional helicopters;
- Empty weight fraction: less than 63%;

II. Setup and activities

a. Structural Concepts & Materials – WP2.2.1

The general structural and construction concepts will be established in permanent interaction with the Project leader (WP2.1.1), with general engineering teams (WP2.2.2), with the teams working on the wing and tail in the ITD Airframe and all other teams in charge of components having interfaces with the central fuselage (WP2.3, WP2.6, WP2.7, WP2.8, WP2.11). Specifications and interfaces definitions will be agreed at the PDR. It is anticipated that different principles may be selected for different airframe substructures corresponding to specific size, geometry and typical load pattern. In particular for the central and front fuselage sections, a hybrid structure combining metallic and composite sections or members may be considered.

b. Stress Analysis & Design Optimization - WP2.2.2

State-of-the-art design techniques e.g. topological optimization will be implemented taking full advantage of most recent materials and production techniques such as fiber or tape placement or out of autoclave curing. For stress analysis, the design and optimization process will rely on linear FE models covering specific fuselage segments or parts with accurate local resolution. Technology and construction trials will be performed on
specimens, parts and small substructures as far as necessary to secure a reliable design. A first Partner activity has already been identified in WP2.2.6.

c. **Fast Prototyping - WP2.2.3**

The front and central fuselage sections will be manufactured. It is expected that the construction methods will require limited tooling and will use available machines and flexible robots to produce all parts in less than 14 months between design freeze and delivery for demonstrator assembly. In addition to the demonstrator parts, it may be necessary to produce some test articles for testing in WP2.2.4. A first Partner activity has already been identified in WP2.2.7.

d. **Virtual and Physical Structural Tests - WP2.2.4**

Several airframe numerical models will be elaborated in order to analyze the full airframe in different conditions: vibratory behavior, deformation and stress under limiting loads. The numerical predictions will be supported by experimental results in areas where they are considered insufficiently reliable. For instance, it may be deemed worthwhile to perform a structural test on the central fuselage barrel. In addition, a full size airframe mock-up (not representative of actual materials and resistance) will be produced as soon as the airframe geometry is defined in order to have it evaluated by panels of crews and passengers for cabin and cockpit access, and functionality of doors and equipment for different missions i.e. manipulation of hoist, stretchers, etc.

e. **LifeRCraft airframe – WP2.2.5**

LifeRCraft Airframe is the Core partner Strategic Topic FRC2.2-1: it includes the cabin, the cockpit and integrates the main systems of the aircraft. The activities cover the structural design according to Airbus Helicopters specification and architecture, the stress analysis and the manufacturing of the demonstrator airframe.

f. **Fuselage Stress Analysis & Design Optimization – WP2.2.6**

This WP concerns the Partner topic within Airframe structure: FRC2.2-2 in connection with WP2.2.2.

g. **Fuselage Fast Prototyping techniques – WP2.2.7**

This WP concerns the Partner topic within Airframe structure Partner Topic FRC2.2-3 in connection with WP2.2.3.
III. High-Level WBS

Figure 8.14 – WP2.2 High-Level WBS
IV. Added value versus state-of-the-art

The WP will produce a new airframe concept (front and central fuselage) featuring an extremely light structure and accommodating the required cabin volume with low drag shape and wide access door for versatile usage (pax, SAR, EMS) and will mature it up to TRL6;

This structure will employ as far as possible environment-friendly materials and will be built fit for long life by means of cost effective and energy efficient production methods, to be substantiated with Life Cycle Assessment tools;

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<tbody>
<tr>
<td>WP2.2</td>
<td></td>
<td>Airframe</td>
<td><strong>Scope</strong>: front &amp; central fuselage up to tail and wing interfaces (not pressurized).</td>
<td>TRL6 for extremely light structure, accommodating required cabin volume with low drag shape and wide access door for versatile usage (pax, SAR, EMS); Green materials, cost efficient production methods; Life Cycle Analysis. Contribution to low empty weight fraction.</td>
<td>CS ED, GRC6, CORINNE, Nat. R&amp;I projects</td>
<td>AHG, Core Partner and Partners</td>
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<td>N/A</td>
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<td>Tail unit</td>
<td><strong>Performed in ITD Airframe HVE4.1</strong></td>
<td><strong>Test articles &amp; substantiation provided by ITD Airframe</strong></td>
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<tr>
<td>N/A</td>
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<td>Wing</td>
<td><strong>Performed in ITD Airframe HVE1.1</strong></td>
<td><strong>Test articles &amp; substantiation provided by ITD Airframe</strong></td>
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V. Partnerships

- In WP2.2.5, aerostructure industry, possibly supported by an industrial laboratory featuring advanced production equipment, having excellent track record in the optimisation of composites and/or hybrid metallic-composite structures, based on in-depth experience of modelisation of materials and structures, advanced production processes and able to design and prototype the front & central airframe sections matching demanding weight and resistance specifications within the project schedule;
- In WP2.2.6, aerostructure design office, possibly supported by an industrial laboratory, institute or university having experience in structural stress analysis for metallic and composite structure (FE models, design optimization...).
In WP2.2.7, aeronautic industry or industrial laboratory featuring advanced production equipment able to prototype with limited tooling high performance structural components (lightweight, complex shape, high resistance....)
VI. Schedule

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<td>WP 2.2.2 Stress Analysis &amp; Design Optimization</td>
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<td>WP 2.2.4 Virtual &amp; Physical Structural Tests</td>
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<td>WP 2.2.5 LifeRCraft airframe, design stress analysis and manufacturing</td>
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8.7.12 Landing System – WP2.3

I. Relevance and technical objectives

In contrast with conventional helicopters, a fast rotorcraft calls for a fully clean aerodynamic fuselage when the landing gear is retracted, with the wheels lodged within the surface profile and landing gear doors tightly adjusted. Due the peculiar LifeRCraft architecture with propellers located at the blade tips, the main legs must be quite long in order to allow for landing on sloping terrain or with strong lateral winds. Consequently, the landing system retraction requires a kinematic arrangement more complex than for helicopters or turboprop aircraft. It will also tend to become significantly heavier, that is why design efforts are to be focused on making the landing system as lightweight as possible, in order to match the general objective of empty weight ratio less than 63%.

II. Setup and activities

a. General Specification & Interfaces - WP 2.3.1

In permanent interaction with the Project leader (WP2.1.1) and with the teams in charge of flight/ground loads (WP2.1.2), airframe structure (WP2.2), the general landing system kinematics and sizing requirements will be established. Specifications and interfaces definitions will be agreed at the PDR.

b. Design & Optimization - WP 2.3.2

It is anticipated that some massive load carrying parts could be made of composites such as MMC (combining lightweight high resistance fibers in a metallic matrix). A selection between several candidate solutions will be performed and the selected one will be optimized and evaluated for compliance with the specified conditions. A first Partner activity has already been identified in WP 2.3.6. This WP covers internal activity, relevant partner activity is within WP 2.3.6

c. Manufacturing - WP 2.3.3

A functional mock-up of the landing gear able to simulate the extension and retraction will support the validation of the kinematics. It will allow optimizing the operation of the doors. Then the whole landing system will be manufactured. It is expected that a first test article could be delivered 12 months after design freeze for characterization and drop tests (WP3.5). The complete flightworthy landing system will be delivered in time for the demonstrator assembly. The actuation subsystem will be provided by WP2.3.4. A first Partner activity has already been identified in WP 2.3.6.

d. Actuation & Control - WP 2.3.4

Based on specifications issued in WP2.3.1, a comparative study of hydraulic vs. electrical actuation will be conducted. The best solution in terms of weight and energy savings considering the indirect effects on aircraft hydraulic and electrical systems will be down selected. It is anticipated that an innovative electrical actuator could satisfy light weight and low maintenance in service requirements. The chosen solution will be designed in full details and realized in time for assembly with landing system developed in WP2.3.3. Should the electrical option be retained, the possibility to incorporate an electrical taxing system will be studied (in continuation with
an earlier study *Clean Sky* GRC 3.5.3), but this will not be implemented on the flight demonstrator owing to lack of APU.

e. **Component testing - WP 3.5**

Beside specimen and part tests performed in WP2.3.2, 2.3.3 and 2.3.4, a complete evaluation in laboratory of the landing gear is required before its integration into the demonstrator. It includes stiffness characterization and drop tests. After demonstrator assembly, it will be tested for ground resonance during the dynamic identification tests. Follow-Up of flight tests will be ensured to check proper landing system operation and validation of the TRL 6 milestone.

f. **Landing gear for LifeRCraft - WP 2.3.6**

This is a partner Topic FRC2.3-1 in the Landing System WP in connection with WP2.3.2 and 2.3.3.

III. **High level WBS**

![Figure 8.15 – WP3 High-Level WBS](image-url)
IV. Added value versus state-of-the-art

Technology for landing system (including actuation) fit for demanding compound rotorcraft specifications ready and validated at TRL6.

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<tr>
<td>WP2.3</td>
<td></td>
<td>Landing System</td>
<td>Specific landing system architecture &amp; kinematics, long legs, fully retractable (low drag); Composite materials to be considered for weight reduction; Electrical actuation; Electrical taxiing to be studied, but not demonstrated. Kinematic test, characterisation and drop tests.</td>
<td>TRL 6 maturity for very light weight, retractable landing system suited for fast rotorcraft. Contribution to low empty weight fraction.</td>
<td>CS GRC3 and SGO</td>
<td>AHG, Indus. companies with track record on light landing systems, elec. actuation</td>
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V. Partnerships

- In WP2.3.6, industrial company having large experience in landing gear design (LG OEM) will perform the landing gear design and optimization in permanent interaction with the Project leader (WP2.1.1) and the teams in charge of flight/ground loads (WP2.1.2) and airframe structure (WP2.2). It will perform the fast prototyping activities necessary to prepare the landing gear functional mock-up.

- This company will also interface with an industrial company having experience in electrical actuator development which will be in charge of WP2.3.4.

- In case the Partner in charge of WP2.3.6 does not the capability to perform some tests planned in WP2.3.5, scientific laboratory with excellent background in landing gear tests could perform this testing in close relationship with LG OEM and the teams in charge of flight/ground loads (WP2.1.2).

VI. Schedule
## ACTIVITY

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<td>WP 2.3.3 Manufacturing</td>
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<td>WP 2.3.5 Component Testing</td>
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      - WP 2.3.2 Design & Optimization
      - WP 2.3.3 Manufacturing
      - WP 2.3.4 Actuation & Control
      - WP 2.3.5 Component Testing
      - WP 2.3.6 Landing gear for LifeRCraft airframe

- **2014**
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- **2015**
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- **2016**
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- **2017**
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- **2018**
  - 7
- **2019**
  - 8
- **2020**
  - 9

- **Drop test**
- **Mock-up**
- **Functional mock-up**
- **Flightworthy mock-up**
- **Functional mock-up**
- **Drop test**
- **Flightworthy mock-up**
- **Drop test**
- **Flightworthy mock-up**
- **Drop test**
- **Flightworthy mock-up**
- **Drop test**
- **Flightworthy mock-up**
- **Drop test**

### WP 2.3 - Landing System TRL

- WP 2.3.1 General Specification & Interfaces
- WP 2.3.2 Design & Optimization
- WP 2.3.3 Manufacturing
- WP 2.3.4 Actuation & Control
- WP 2.3.5 Component Testing
- WP 2.3.6 Landing gear for LifeRCraft airframe
Lifting Rotor – WP2.4

I. Relevance and technical objectives

The lifting rotor, especially the blade design impacts very strongly the hovering performance and the noise in all flight conditions. In addition, the aerodynamic drag of non-lifting parts (hub, blade roots, pitch control system, shaft and pylon) represents a large fraction of the overall airframe drag, typically between 25% and 40% for conventional helicopters. In Clean Sky, the work packages GRC1 and GRC2.1 address respectively the blade design and the hub drag reduction, with substantial gains announced for conventional helicopter configurations.

For a compound rotorcraft cruising much faster, it is even more essential to reduce the airframe drag in order to secure an improved L/D_e ratio for the whole vehicle. Concerning the rotor blades, more thrust is required in hover in order to compensate the additional empty weight and the aerodynamic down load due to the wing partially submerged in the rotor downwash. The blade design has to minimise these specific penalties in hover and also maintain sufficient performance in high speed with reduced lift and reduced RPM.

Compliance with some of the high level technical objectives very much depends on rotor design:

- Peak vehicle fineness L/D_e: improvement+20% w.r.t. conventional helicopters;
- Empty weight fraction: less than 63% (MTOW depending on rotor performance);
- Noise level (in EPNdB) and acoustic footprint less than conventional helicopters

The X³ test bed flights performed before this demonstration program allowed to open the flight domain of a conventional rotor system toward very high speeds and identify the flight loads and specific design adaptations required to secure smooth operation across the whole flight envelope. Therefore no further specific tests are required before demonstration flights to de-risk the main rotor system [TF27] in the high speed domain.

II. Setup and activities

a. General Specification & Interfaces - WP 2.4.1

In permanent interaction with the Project leader (WP2.1.1) and aerodynamicists in charge of the overall aerodynamic configuration (in WP2.1.2), the specification, interfaces and technical objectives for blades and rotor non lifting parts will be established, taking into account the project constraints in terms of compatibility with other components, project schedule and cost. Two sets of blades will be specified, each with a different level of risk as further explained below. Should it however appear during the preliminary study that the predicted difference in overall performance benefits between the two set of blades is not sufficient to justify the full development of two different blade designs, it may be decided to design and realize a single configuration that combines good performance and an acceptable level of risk and transfer the saved budget to another component that deserves more work than initially anticipated.

b. Optimized Blade Design - WP 2.4.2

Based on CFD tools and optimization methodology exercised in CS-GRC1 and other previous projects, a multipoint optimization aiming at the best trade-off between hover performance, cruise flight performance and noise emission will be performed. The design process will consider not only the aerodynamic aspects but also impact on the rotor structural design, control loads, dynamics and vibration. A level of risk classified as
“Medium” (Probability: Medium; Severity: Medium) will be accepted as long as the predicted benefits match the objectives set in WP2.4.1.

c. **Blade Alternate Solution - WP 2.4.3**

This work package will be implemented in order to mitigate the risk accepted in the more challenging design of WP2.4.2. The blade design will be derived from an existing helicopter blade departing only slightly from the geometry and construction of an existing design with some modifications inferred from the lessons learnt after X3 high speed flight testing. Design modifications will be decided following a cautious approach, adapting them to specific sizing and constraints of the new demonstrator and to the new flight domain. Level of risk: “Low” (Probability: Low; Severity: Low of Medium)

d. **Hub & pylon adaptation & Drag Reduction - WP 2.4.4**

Drag reduction solution tested successfully in *Clean Sky* GRC2.1 (TRL6 reached) such as hub cap, blade sleeves and roots, pylon cowlings will be adapted to the specific hub and mechanical configuration and size of the demonstrators. New solutions with lower maturity upon WP2.4.4 start could also be proposed as options if their predicted benefits in isolation or in combination of the basic solutions appear more attractive. The mechanical parts of the hub and pylon might be derived from existing helicopter hardware with minimal adaptation; a more innovative solution could however be designed and developed in case stronger construction and/or lower drag requirements would make it necessary. Specific wind tunnel tests are planned to select and validate the alternative solutions prior design freeze, following a method similar to the one being implemented in *Clean Sky*. Dynamic system suspension might derive from existing helicopter hardware with the necessary adaptation to be compatible with the optimised blade dynamic tuning and with the aircraft architecture.

e. **Icing Protection Study - WP 2.4.5**

Although the demonstrator will not be equipped with an icing protection system, the design of all components including the rotor system has to be compatible with the eventual insertion of such a system. A study will be conducted to assess the impact of high speed and variable RPM on an icing protection specification. In particular, the technology, power demand, interface and volumes required for such a system for the lifting rotor will be documented using advanced numerical tools taking into account state of the art anti-/de-icing technologies. [The TF28] high level of risk involved in developing an icing protection system under the budget constraint of the LifeRCraft demonstration program does not allow the project to include the realisation of a flightworthy ice protection system on the demonstrator.

f. **Manufacturing - WP 2.4.7**

The blade sets, pylon and hub incorporating drag reduction fairings or devices (including selected alternate solutions) will be realized and delivered in time for Iron Bird tests (WP2.13.1) and demonstrator assembly (WP2.13.2).
g. **Follow-Up of LifeRCraft Demonstration Tests - WP 2.4.5**

The teams and partners acting in WP2.4.1, to 2.4.4 will exploit the results obtained during the demonstrator tests and in case of deviation w.r.t. to expected behavior, will analyze reasons for these deviations and propose mitigation measures, if needed.

III. **High level WBS**

![High-level WBS Diagram](image)

**Figure 8.16 – WP2.4 High-Level WBS**

IV. **Added value versus state-of-the-art**

*Clean Sky* will allow reaching TRL 5 for helicopter blade optimization by end of 2016. WP4.2 will exploit the same tools for the optimisation in high speed flight. TRL 5 will be achieved for high speed blades with the Iron Bird tests and TRL6, with the flight demonstration.

Concerning drag reduction technologies, TRL 6 will be reached for conventional helicopters in 2016 (*Clean Sky* flight demos). WP2.4.4 will adapt and implement similar solutions for the LifeRCraft configuration, with TRL5 reached after wind tunnel tests and TRL6, with the flight demonstration.

Regarding the icing protection system, it is expected that an innovative solution, lighter and less complex than conventional electro-thermal boots and which consumes less power, can be developed up to TRL 4 (lab test on blades sections and/or wing sections). Further technology development could take place in parallel or after *Clean Sky 2* completion, with the conventional technology being still available as a back-up solution for a future product.
**V. Partnerships**

- In WP2.4.2, Partner(s) having excellent track record in CFD, coupled CFD-CSM and numerical optimization applied to helicopter rotors;
- In WP2.4.4, Partner(s) with experience in drag reduction techniques for helicopter hub and pylon and the capacity to build wind tunnel test models with rotating rotor head and test them for comparison with analytical predictions;
- In WP2.4.5, Partner(s) with track record in the simulation of ice accretion and icing protection operation on large rotating blades;
- In WP2.4.5, Partner(s) proposing innovative icing protection device suitable for rotor blades with experimental background and simulation capability (TRL 5 or more in other applications).

**VI. Schedule**

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**Technologies / Activities**

- Hub cap, blades sleeves and pylon fairings: new, optimized for drag reduction;
- Blades: new design optimized for LifeRCraft flight envelope and variable RPM;
- COTS or adapted: hub and swashplate assembly;
- Provision for icing protection capability.

**Results / Added value**

- TRL6 maturity for new blade design, specific for compound rotorcraft flight envelope;
- Green materials, cost efficient blade production methods
- Rotor Figure of Merit contribution to MTOW;
- Rotor L/D_e contribution to fuel burn reduction and range extension

**Background**

- CS GRC1, GRC2, Nat. R&I projects

**Lead Actors / Key Contributors**

- AHG, Research Institutes, industrial Partners
8.7.14 Propellers – WP2.5

I. Relevance and technical objectives

The propellers have to perform two functions: first, to provide yaw control and anti-torque balancing the lifting rotor torque in hover and low speed conditions and second, to provide the largest part of propulsive force in high speed flight. Both functions have to be fulfilled with maximum efficiency i.e. with the lowest possible power consumption and the design optimized for each these functions considered individually is quite different and therefore required a careful trade-off. In addition, the propellers may generate noise in their rotation plane which is a serious concern both for the impact on ground and on the passengers’ and crew’s comfort. The sizing of blades, the selection of RPM schedule and the design of 3D blade shape will allow reducing that noise to an acceptable level, similarly to what has already been achieved for regional aircraft and general aviation. Compliance with some of the high level technical objectives very much depends on the propeller design in particular:

- Peak vehicle fineness \( L/D_e \): improvement +20% w.r.t. conventional helicopters (propeller efficiency contributes to fineness);
- Empty weight fraction: less than 63% (MTOW depending on power consumed by propellers in hover);
- Noise level (in EPNdB) and acoustic footprint less than conventional helicopters.

II. Setup and activities

a. WP 2.5.1 General Specification & Interfaces

This WP will be conducted in permanent interaction with the Project leader (WP 2.1.1) and other teams in charge of vehicle aerodynamics (in WP 2.1.2), drive system (WP 2.6), actuators (WP 2.9) and flight control (WP 2.12). The specification, interfaces and technical objectives for propellers will be established, taking into the project constraints in terms of compatibility with other components, project schedule and cost.

b. WP 2.5.2 - Optimized Propeller Design

Based on knowledge and tools acquired through earlier projects regarding optimization of propellers, prop-rotors and tail rotors (for turboprop aircraft, general aviation, tilt-rotor aircraft, conventional helicopters), a multipoint optimization will aim at the best trade-off between anti-torque, yaw control, propeller efficiency and noise signature. The design process will consider not only the aerodynamic aspects but also the impact on the hub, pitch control constraints, in particular pitch control loads, and certification requirements as bird strike. The level of risk of this solution versus the benefits in terms of performance, weight and certificability will be evaluated. A first Partner activity has already been identified in WP 2.5.8 on aero acoustic optimization.
c. **WP 2.5.3 – Propeller alternate solution**

In case the optimised design may appear technically risky, a back-up design solution closer to an already available propeller solution should be also proposed. The decision will be to either down select one of the two designs or to develop both of them, should it be considered appropriate and affordable. This solution will be adapted to the aircraft concept on the basis of the lessons learned after X3 high speed flight while testing and taking benefit of the flexibility given by the selected existing technology.

d. **WP 2.5.4 Icing Protection Study**

Although the demonstrator will not be equipped with an icing protection system, the design of all components including the propellers has to be compatible will insertion of such a system. A study will be conducted to select the best candidate technology for icing protection of the LifeRCraft propellers. The power demand, interface and volumes required for such a system will be documented using advanced numerical tools taking into account state of the art anti-/de-icing technologies and the selected blade materials and structure.

e. **WP 2.5.5 Propeller Design & Realization**

The detailed design of the blade structure and adaptation of the hub and pitch change mechanism will be conducted, with some specimen or component tests as needed. The propellers needed for the bench test, for the Iron Bird and for the flight demonstrator will then be produced and delivered in time for these tests. The usage of environment-friendly materials e.g. natural fibers for blades will be considered along with the full propeller Life Cycle impact on the preservation of natural resources and energy.

In accordance with the studies done in the frame of WP 2.5.2 and 2.5.3, one or two propeller solutions , an innovative one and a more conventional one, featuring different blade shapes and/or different hub architectures will be designed in detail and manufactured. If two solutions are developed, the selection between these two options will be based on the best compromise between expected technical benefits and risks after a minimum of evaluation on propeller bench tests.

A first Partner activity has already been identified in WP 2.5.9.

f. **WP 2.5.6 Propeller Bench Test**

At least one, possibly two full scale propellers will be tested for performance on an outdoor static rig. In addition to steady operation performance, the dynamic response to fast pitch changes will also be measured.

g. **WP 2.5.7 Propeller Wind Tunnel Test**

A Mach-scaled propeller model (with two blade sets, should this be deemed necessary), will be realized and tested in a wind tunnel capable of LifeRCraft speed domain with the simulation of aircraft environment. This WP covers internal activity while partner related activity is within WP 2.5.8

h. **WP 2.5.8 Propeller aeroacoustic optimisation**

This WP is the Partner topic in Propellers : FRC2.5-1 in connection with WP 2.5.2 and 2.5.7.

i. **WP 2.5.9 Propeller mechanical design and manufacturing**
This WP is the Partner topic in Propellers: FRC2.5-2 in connection with WP 2.5.5. The Partner performing this WP might also perform the propeller bench test (WP 2.5.6), depending on available test facilities & equipment.

j. **WP 2.5.10 Follow-Up of LifeRCraft Demonstration Tests**

The teams and partners acting in WP2.5.1, 2.5.2, 2.5.4 will exploit the results obtained during the demonstrator tests and in case of deviation w.r.t. to expected behavior, will analyze reasons for these deviations and propose mitigation measures, if needed.

### III. High level WBS

![WP 2 IADP Rotorcraft LifeRCraft Demo](image)

**WP 2.5**
- Propellers
  - WP 2.5.1 General specification & Interfaces
  - WP 2.5.2 Optimised Propeller design
  - WP 2.5.3 Propeller alternate solution
  - WP 2.5.4 Icing Protection Study
  - WP 2.5.5 Propeller Design & Realisation
  - WP 2.5.6 Propeller Bench Test
  - WP 2.5.7 Propeller Wind Tunnel Test
  - WP 2.5.8 Propeller Aero-acoustic optimization
  - WP 2.5.9 Propeller mechanical design and manufacturing
  - WP 2.5.10 Follow-Up of LifeRCraft Demonstration Tests

Figure 8.17 – WP2.5 High-Level WBS

### IV. Added-value versus state-of-the-art

This WP will secure the TRL6 maturity for an advanced propeller design matching specific compound rotorcraft dual functions, with low noise signature and high efficiency contributing to fuel burn reduction and range extension. Incorporation of environment-friendly materials and the impact of the propellers whole Life Cycle will be considered. Provisions will be made in the design for an icing protection system although it will not be realised on the flight demonstrator.
Clean Sky 2 Joint Technology Initiative in Aeronautics

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|       |       |       | CFD for new blade design optimized for best dual function trade-off (yaw control, propulsive efficiency) and noise reduction; COTS or adapted: hub and pitch change mechanism, Provision for ice protection capability; Isolated prop tests:  
- Full scale on static rig  
- Down scaled in wind tunnel | TRL6 maturity for new propeller design, specific for compound rotorcraft functions; Environment-friendly materials (esp. for blades). Prop efficiency contribution to fuel burn reduction and range extension | X3 test bed project, DART & NICETRIP (tilt-rotor), CESAR (SAT) | AHG, Research Institutes, prop manuf. (synergy with SAT possible), test center, wind tunnel op. |

V. Partnerships

- In WP2.5.4, Partner(s) with track record in the simulation of ice accretion and icing protection systems on propellers;
- In WP2.5.4, Partner(s) proposing innovative icing protection device suitable for propellers with experimental background and simulation capability (TRL 5 or more in other applications);
- In WP2.5.6, Laboratory having capacity to adapt or develop a test rig suitable the full scale propeller tests and conduct the steady and transient performance tests. Capability to perform local stress and flow measurements will be appreciated, in order to correlate with the computational predictions;
- In WP2.5.7, Laboratory having capacity to adapt or construct a Mach-scale propeller model and perform accurate wind tunnel tests in its own facilities. Capability to perform local stress and flow measurements i.e. PIV will be appreciated, in order to correlate with the computational predictions;
- In WP2.5.8 Partner(s) having excellent track record in CFD, coupled CFD-CSM and numerical optimization applied to propeller blades for general aviation, turboprop aircraft and tilt-rotor aircraft;
- In WP2.5.9, Industrial partner with capacity and experience with the design and production of propellers in the power range relevant for LifeRCraft. The capability to propose innovative construction solutions and to realize prototype parts in a short time frame will be required.
## VI. Schedule

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8.7.15 Mechanical Drive System – WP2.6

I. Relevance and technical objectives

The Mechanical Drive System remains a significant part of a compound rotorcraft as for a conventional helicopter. It must insure the transmission of the power from the engine(s) to the main rotor and the propellers thanks an appropriate speed reduction ratio with a suitable safety level.

- High speed shaft connecting each engine to the main gearbox;
- A main gearbox (MGB) adding the power of each engine with an upper output to drive the main rotor and 2 lateral outputs to drive the propellers;
- Two propeller drive shafts in the wings;
- Two propeller gearboxes (PGB) installed each in a nacelle located near the tip of each wing and driving each a propeller. The PGB output shaft must accommodate the pitch control system of the propeller.

Even if the Mechanical Drive System uses similar technology as conventional helicopter, the compound configuration leads to important differences in the system operation (power distribution following flight phase, loads in housings, variable speed…) which needs to take a particular attention at its design to obtain a safe and reliable operation.

In addition, the system could include a feature allowing de-clutching on ground one or two propellers in order to facilitate operation around rotorcraft when engine(s) and rotor stopping is not suitable.

The optimisation of this system taking into account of the specific compound specific operation is mandatory in order to:

- have an optimised weight for a system highly contributing to empty weight;
- insure a high level of safety as the Mechanical Drive System has a high level of criticity as for helicopter;
- secure a high level of reliability with an acceptable level of maintenance.

A HUMS system contributes to reach the suitable level of safety and reliability.

II. Setup and activities

a. WP 2.6.1 General Specification, Architecture & Interfaces

This WP will be conducted by the team in charge of drive system architecture (WP2.6) under the monitoring of the Project leader (WP2.1.1) and in permanent interaction with other teams: airframe structure (WP2.1), Lifting rotor (WP2.4), Propellers (WP2.5), Shaft and Gearbox design (WP2.6.2 to 2.6.5), Power Plant (WP2.7), Electrical system (WP2.8), actuators (WP2.9) and flight control (WP2.12). The specification, interfaces and technical objectives for drive system will be established, taking into the project constraints in terms of compatibility with other components, project schedule and cost.

b. WP 2.6.2 – High speed shafts Design & Realization

The detailed design of the high speed shafts which connect the engine outputs to main gear box inputs will be based on the knowledge acquired on helicopter design and X³ experience.
c. **WP 2.6.3 – Main Gearbox Re-design & Realization**

The specification and the detail design of the main gearbox will partly reuse the design of a rotorcraft Main GearBox (MGB) but will include specifically designed parts to insure the drive of the propellers with the suitable power distribution: the experience gained on X³ will be reused for the design of the specific parts. Long life, low maintenance objectives and REACh constraints will be taken in consideration for the selection of the materials and surface protection. Partner activity has already been identified in WP 2.6.9.

d. **WP 2.6.4 – Propeller Drive Shafts Design & Realization**

A specific design of super-critical drive shaft with high torque loads will be done taking into account of the operation inside a lifting wing. New design and production techniques will be considered to meet these challenging specifications. Long life, low maintenance objectives and REACh constraints will be taken in consideration for the selection of the materials and surface protection. A first Partner activity has already been identified in WP 2.6.10.

e. **WP 2.6.5 – Propeller Gear Boxes Design & Realization**

The specification and design of Propeller GearBoxes (PGB) will capitalize not only the knowledge and lessons learnt from X³ experience but also the expertise that some partners may have gained with different types of propulsion gearboxes. A specific attention will be devoted to the integration of the propeller pitch control system. Partner activity has already been identified in WP 2.6.9.

f. **WP 2.6.6 – Extended HUMS**

The condition of operation of a compound drive system is different of conventional helicopter drive system. The experience gained thanks to X³ will be analysed and specific measurements will be done during bench and flight tests in order to start to acquire data to prepare an adapted HUMS. The parameters to be measured and the interface with the sensors will be defined in accordance with the responsible of WP’s 2.6.2 to 2.6.5. [The TF29] limited duration and budget of the LifeRCraft demonstration program does not allow integrating a complete HUMS system on the flying demonstrator.

g. **WP 2.6.7 – Mechanical Bench Tests**

Mechanical bench development tests will be performed mainly on a Mechanical Drive System Rig based on the Back-to-Back principle where MGB and each PGB will be installed to achieve a high level of torque loading. These back-to-back tests will permit to identify housing deflections and compatibility with gear and bearing functions with torque level higher than we will reach on the flying demo. This rig will also be used to perform the minimal mechanical endurance required for Permit-to-Fly.

This WP is a crucial development milestone for the MGB and PGB subsystems that will clear the way for the whole drive system maturity to reach TRL 5 after the demonstrator ground tests (WP2.13.4).
h. **WP 2.6.8 – Follow-up of LifeRCraft Demonstrator Tests**

The teams and partners acting in WP2.6.1, 2.6.2, 2.6.3, 2.6.4, 2.6.5, and 2.6.6 will exploit the results obtained during the demonstrator tests and in case of deviation w.r.t. to expected behavior, will analyze reasons for these deviations and propose mitigation measures, if needed.

i. **WP 2.6.9 – LifeRCraft drive system**

This Core Partner W1Strategic topic FRC2.6-1 is in connection with WP 2.6.3 & 2.6.5. Two propeller gearboxes (LH & RH) and specific MGB modules have to be developed for the compound MGB (MGB derived from an existing MGB). The activities cover the design according to Airbus Helicopters specification and architecture, the stress analysis, the manufacturing of the gearboxes for ground tests and flight tests, and the analysis of the tests results.

j. **WP 2.6.10 – Propellers coupling shafts**

This W2 Partner topic FRC2.6-2 is in connection with WP2.6.4.

III. **High level WBS**

![High level WBS Diagram](image)

Figure 8.18 – WP2.6 High-Level WBS

IV. **Added-value versus state-of-the-art**
This WP will secure the TRL 6 maturity for a compound Mechanical Drive System in the way to obtain a lightweight, reliable and long life system for this rotorcraft concept. Provision will be taken in the bench and flight tests to start to accumulate data for an extended HUMS adapted to this type of transmission.

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<td>WP2.6</td>
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<td>Mechanics Drive System</td>
<td>New design: Main Gear Box input module, lubrication system, engine-MGB links; lateral shafts, Prop Gear Boxes; all designed for LifeRCraft-specific RPM and torque variation; COTS or adapted: Main Gear Box casing and upper reduction gears, suspension system</td>
<td>TRL6 maturity for drive chain architecture specific to compound rotorcraft; Materials and surface treatments compliant with REACH</td>
<td>X3 test bed project</td>
<td>AHG, Core-partners, partners, suppliers</td>
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|       |       |                   | Testing:  
  • Gear boxes (3 campaigns on mechanical rig)  
  • Rotor System Rig (see WP3) | Weight savings contributing to low empty weight fraction. | CS GRC6, Nat. R&I projects | |

V. Partnerships

- In WP 2.6.9, industrial manufacturer having excellent experience in casting, roll bearings and gear design and manufacturing.
- In WP 2.6.2 and WP 2.6.10, industrial laboratory or research centres with capacity to analyse operation and behaviour of flexible couplings, industrial partners having high experience in development and manufacturing of flexible couplings and/or drive shafts.
- In WP 2.6.6, industrial laboratories or research centres having excellent experience in dynamic signal analysis.
### VI. Schedule

#### WP2.6 - Mechanical Drive System

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#### TRL

- PDR: Preliminary Design Review
- CD: Critical Design Review
- TR: Technology Readiness Level
- F: Flightworthy parts delivered
- BtB: Back to Back
- S: System Sig
8.7.16 Power Plant – WP2.7

I. Relevance and technical objectives

The compound rotorcraft needs a suitable shaft power to achieve the targeted take-off and speed performance. Power sizing considerations are changed in comparison with conventional rotorcraft: cruise speed should be the main sizing condition versus hovering flight for conventional helicopters. One Engine Inoperative (OEI) requirements will have to be assessed as it may also constitute a performance limit at take-off. The improvements of engine itself in term of fuel consumption particularly at cruise power level and specific weight are key points. The optimisation of the OEI ratings with limited impact on engine efficiency (specific fuel consumption, weight and cost) to improve the compound rotorcraft performance after an engine failure has to be analysed. The broad range of power turbine speed variation between hover and high speed flight appears as a critical additional specification typical of fast rotorcraft. The adaptation of an existing engine to match these specific requirements is placed under the responsibility of the engine manufacturer.

In term of engine integration, the optimisation between the upper cowlings drag, installation losses and weight has to be reconsidered to reach the level of targeted performance as described in the § 1.7.3. The protection against the environmental conditions (icing, snow, sand and FOD) has to be taken into account in the installation design. The inlet and exhaust configurations have to ensure enough sound filtering and/or absorption for the engine noise sources to remain a level well below the other rotorcraft noise sources. Engine integration is placed under the responsibility of the rotorcraft integrator with participation of the engine manufacturer [TF30]. The engine technology, rating and installation dramatically impact the compliance with the high level technical objectives in terms of fuel consumption and gas emission, range and speed.

II. Setup and activities

a. WP 2.7.1 – Engine specification and interface

This WP will be conducted in permanent interaction with the project leader (WP2.1.1) and other teams in charge of vehicle aerodynamics and performance (WP2.1.2), airframe (WP2.2), drive system (WP2.6) and Flight control (WP2.12). The specification, interfaces and technical objectives for the power plant and engines will be established, taking into the project constraints in terms of compatibility with other components, project schedule and cost.

b. WP 2.7.2 – Turboshaft engine adaptation

This WP will be conducted by the manufacturer of the selected engine in permanent interaction with the project leader (WP2.1.1). For the flying demo, it will be mainly to adapt the engine fuel control (FADEC) to the specific need of compound rotorcraft (variable output-shaft speed, mechanical drive system characteristics) to adapt the accessory gearbox to the selected starter generator (WP2.8) and optimize the power rating structure to compound power requirement following the flight conditions. The engine manufacturer will provide data on potential engine technology improvements and engine models in support to Technology Evaluation (WP2.1.6) and Project Synthesis (WP2.13.5). For this purpose, this work package will be linked to Engines ITD WP3 [TF31]. The WP 2.7.2.2 Turboshaft engine adaptation includes the W2 Partner Topic FRC2.7-1.
c. **WP 2.7.3 – Optimized Engine installation**

This engine integration will be defined in order to limit the engine installation losses in hover and in fast cruise and simultaneously reducing the overall drag of upper cowlings. It will impact the architecture of the upper deck, the design of the air inlet to be done in accordance with WP2.7.4, the engine compartment ventilation and the exhaust system. The study will include CFD analysis to obtain an optimized design. Noise and hot gases interference with tail fuselage will be taken in consideration. Engine noise filtering and/or absorption will also considered as part of the design trade-offs.

d. **WP 2.7.4 – Inlet Icing & FOD Protection Study**

The air inlet design will incorporate solutions with the target to protect engine against environmental conditions as icing, operation in snowing conditions and FOD. The design will be based on analysis only and on the experience of the project leader and of the selected engine manufacturer. The full scale tests in simulated icing, snow conditions and FOD as would be required for certification are not part of the demonstration performed under a Permit to Fly. Although the demonstrator will not be equipped with, the integration of removable sand protection will be studied.

e. **WP 2.7.5 – Engine control Interface**

The engine control interface will be defined in accordance with the engine FADEC and sensors interfaces. Appropriate control law for the variable rotor speed will be developed. Engine monitoring display adapted to engine will be installed and a First Limit Indicator will be evaluated (see also WP2.10.2).

f. **WP 2.7.6 – Fuel system**

The fuel system architecture will be defined to insure the storage of the suitable fuel quantity necessary for rotorcraft autonomy without penalty on the external drag (use of fuel storage in wing to be studied) or cabin accessibility and insuring a minimum weight in compliance with CS2 requirements.

g. **WP 2.7.7 – Follow-up of LifeRCraft demonstrator tests**

The teams and partners acting in WP2.7.1 to 2.7.6 will exploit the results obtained during the demonstrator tests and in case of deviation w.r.t. to expected behavior, will analyze reasons for these deviations and propose mitigation measures, if needed.
III. High level WBS

![Diagram](image.png)

Figure 8.19 – WP2.7 High-Level WBS

IV. Added value versus state-of-the-art

This work package will secure the TRL 6 for an advanced compound rotorcraft Power Plant with an efficient engine (low specific fuel consumption), a low level of installation losses within the compound rotorcraft operational envelope (speed, environment) and a low drag engine “nacelle”. Concerning sand protection, a TRL 3 solution avoiding degrading the overall compound rotorcraft performance will be targeted.
V. Partnerships

- In WP 2.7.2.2, engine manufacturer developing innovative solution to improve engine efficiency.
- In WP 2.7.3 and WP 2.7.4, research center or laboratory able to perform computational studies (e.g. CFD) or “light” simulation tests to support identification of an optimised design for air inlet and engine compartment.
- In WP 2.7.6, equipment manufacturer(s) developing an innovative solution in term of CS29 compliant fuel tank bladder and fuel gaging system

VI. Schedule
8.7.17  **Electrical System – WP2.8**

I.  **Relevance and technical objectives**

*Clean Sky* joint efforts in GRC3, SGO and EDS are leading to the demonstration on an integration test bench of a whole range of innovative electrical technologies for smart aircraft including rotorcraft. Most of these technologies will reach TRL5 in 2016. The LifeRCraft demonstrator is a unique opportunity to seamlessly pursue the integration activities up to TRL6 i.e. flight demonstration. This will allow proving the energy savings realized thanks to higher efficient on-board systems, and the possibility to eliminate or, at least, to reduce the number and size of hydraulic subsystems.

The objective is to embark electrical systems that will also allow reducing the total weight of on-board energy systems. The electrical system will be based on a 28 VDC/270 VDC network offering the best compromise taking into account the specificity of the compound rotorcraft. The detailed configuration of the demonstrator electrical system will be established during the preliminary design phase considering the specific constraints and its description cannot be delivered before reaching that stage [TF32].

II.  **Setup and activities**

a.  **WP 2.8.1 – Electrical System Specification**

The specification of the electrical system will be based on one side on available results from Cleans Sky and on the other side on the vehicle and equipment configuration selected in in WP2.1.1 and WP2.10-2.11-2.12, respectively. The specification will take in due account some constraints from existing equipment being re-employed although not perfectly fit for the flight demonstrator needs (for the sake of project cost and schedule control). It is also anticipated that not of all *Clean Sky* technologies may be appropriate for this rotorcraft configuration and its specific missions. Variable RPM is an important aspect specific to the compound rotorcraft configuration that needs to be properly considered for the electrical system specification as it may restrict the use of a conventional 115 V AC network. Installation of a 270 VDC network will be considered in order to minimize the weight of cables and components for powerful equipment. In addition, it will enable a high performance capability for the engine start function.

b.  **WP 2.8.2 – Electrical generation, distribution system and Lighting**

Generators and engine brushless S/G are being developed in *Clean Sky* compatible with this vehicle. Brushless machines can provide weigh savings. Storage systems embedding Lithium batteries and ultra-capacitors can accommodate conflicting requirements of high peak current during short periods and high storage capacity delivered/charged with for low mean current, and this results in a lower weight of the storage system. Such a storage system is under development and testing in Clean Sky SGO and may be adopted for flight demonstration on LifeRCraft if proven to be mature enough and able to provide a significant weight saving.

The electrical master box could use solid state static contactors which bring some additional weight saving. The corresponding technologies are expected to be mature enough for adaptation and installation on the LifeRCraft demonstrator.

An interior and exterior lighting system will be defined for the demo using existing components or new equipment aiming at incorporating technologies that offer significant improvements in term of weight or drag impact (external lighting).

Integration tests of the complete electrical generation system will be part of WP 2.13.1.
A first Partner activity has already been identified in in WP 2.8.6, 2.8.7 & 2.8.8

c.  **WP 2.8.3 Electrical harness architecture, Integration and manufacturing**
Once the airframe geometry and the electrical equipment positions and interfaces are defined, the architecture and the routing of electrical harnesses will be defined to minimise weight while insuring the suitable level of segregation between safety critical redundant systems according to certification requirements. Then the following step will be to proceed with detailed design of harnesses and equipment supports and harnesses routing brackets. The manufacturing and delivery of the full system is needed after assembly of for the flight demonstrator primary structure.

a. **WP 2.8.4 – Electrical harness technology**

The impact of the 270 VDC will be considered in the selection of the wiring insulation and connector technology. This selection will comply with Eco-Design recommendation (see WP 2.1.5).

b. **WP 2.8.5 – Electrical Integration Rig testing and follow-up of flight demonstrator testing**

The teams and partners in charge of the electrical system design will help defining, preparing and following up specific electrical tests on the electrical integration rig. The electrical system including generators, power storage, electrical master box, converters, networks and main consumers will be assembled and tested on a dedicated electrical rig for validation before installation of flightworthy equipment on the demonstrator. The results and lessons learnt from Clean Sky integration tests with the “Copper Bird” (Eco-Design for Systems) will facilitate the integration process for this innovative electrical system implementing some of the technologies already developed in Clean Sky. Further, the teams and partners in charge of the electrical system design will remain involved during the flight demonstrator ground testing and flight testing phases.

c. **WP 2.8.6 – Electrical Converter**

The W1 Partner Topic in Electrical systems FRC2.8-3 is in connection with WP 2.8.1.

d. **WP 2.8.7 – Electrical Generation**

The W1 Partner Topic in Electrical systems FRC2.8-1 is in connection with WP 2.8.1.

e. **WP 2.8.8 – Electrical storage**

The W1 Partner Topic FRC2.8-2 is in connection with WP 2.8.1.
### III. High level WBS

![WP 2 IADP Rotorcraft LifeRCraft Demo](image)

- **WP 2.8 Electrical System**
  - WP 2.8.1 Electrical system specifications
  - WP 2.8.2 Electrical generation distribution system and lighting
  - WP 2.8.3 Electrical harness architecture, integration & manufacturing
  - WP 2.8.4 Electrical harness technology
  - WP 2.8.5 Electrical Integration Rig testing and follow-up of flight demonstrator testing
  - WP 2.8.6 Electrical convertors
  - WP 2.8.7 Electrical generation
  - WP 2.8.8 Electrical storage

Figure 8.20 – WP2.8 High-Level WBS

### IV. Added value versus state-of-the-art

Many technologies developed in *Clean Sky* will be demonstrated in a relevant environment i.e. integrated into a consistent on-board energy system embarked on a flight demonstrator, demonstrating significant benefits in terms of weight and power off-take savings. The synergy with the Systems ITD will be considered in the selection of the suitable equipment.

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<tr>
<th>WP L1</th>
<th>WP L2</th>
<th>TITLE</th>
<th>Technologies / Activities</th>
<th>Results / Added value</th>
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<th>Lead Actors / Key Contributors</th>
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<td>Electrical System</td>
<td>Redesigned electrical generation. New distribution and routing specific to LifeRCraft architecture, with weight optimization (partially 270VDC)</td>
<td>Weight savings contributing to low empty weight fraction; Efficiency improvements contributing to lower power off-takes from drive train</td>
<td>CS SGO, GRC3, EDS</td>
<td>AHG, equipment manufacturers</td>
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V. Partnerships

Calls for Proposals will be launched for further development of some electrical technologies already investigated in Clean Sky. It is expected that Members or Partners participating in these Clean Sky technology developments will apply and be successful for continuation of their activities toward a higher readiness level.

VI. Schedule

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8.7.18 Actuators – WP2.9

I. Relevance and technical objectives

Due to its compound configuration, the LifeRCraft demonstrator cumulates two sets of flight controls: the same controls as those of a helicopter plus additional trimming surfaces. In total it possesses 8 distinct aerodynamic control variables (including wing flaps). This translates into a high number of actuators of different kinds which are used to secure best possible handling qualities and aerodynamic performance throughout the broad flight envelope (see WP 2.12). Some research activities engaged in Clean Sky SGO on electrical actuation will be pursued toward higher maturity as they enable to enhance flight control with less additional weight.

II. Setup and activities

The specification for all flight control actuators will be defined in liaison with the team in charge of the flight control system (WP 2.12.1).

a. WP2.9.1 - Lifting Rotor Actuators

Existing hydraulic boosters may be used for the demonstrator as the technology of safety-critical EMA actuators of the required power is not expected to be mature soon enough for implementation on a flightworthy rotorcraft. The boosters will be controlled via mechanical linkages as for existing helicopters. Autopilot actuators will also likely be off-the-shelves components.

b. WP2.9.2 - Propeller Flight Control Actuators

The power for pitch is quite high due to combination of large forces and high pitch change rate in case of fast yaw manoeuvres; consequently a hydraulic booster will likely remain the only possible option. One will however consider several options for controlling the hydraulic distributors: either a mechanical linkage running from the propeller to the cockpit though the wings, or a Fly-By-Wire system with electrical actuators. Electrical actuators offer some potential advantages in terms of weight and adaptive combination of yaw and thrust controls. On the other hand, the safe-critical character of propeller control would require fully redundant electrical channels and back-up modes which development may not be compatible with the project schedule and cost envelope. Other architecture options i.e. a partly electrical and partly mechanical system will also be considered. Partner activity has already been identified in WP 2.9.8.

c. WP2.9.3 – Hydraulic generation

A redundant hydraulic generation will be designed to provide the necessary power to lifting rotor and propeller boosters. This system will be designed in accordance with the booster flow and pressure needs, using as far as possible existing equipment. This system might be either centralised to cover needs of all hydraulic actuators or decentralised with separate generation for each propeller: choice to be made during the preliminary design phase.

The detailed configuration of the demonstrator hydraulic system(s) will be established during the preliminary design phase considering the specific constraints and its description cannot be delivered before reaching that stage.

d. WP2.9.4 - Pitch & Yaw Trim Actuators
Actuators on tail surfaces are used to trim the rotorcraft pitch and yaw attitude in high speed flight while the rotor and propeller controls are used for manoeuvres in the full flight envelope. It is assumed that existing actuators or slightly modified ones could meet the needs for the tail surfaces. Partner activity has already been identified in WP 2.9.8.

e. **WP2.9.5 - Wing Flap Actuators**

It is assumed that weight efficient, electrical rotating actuators (slow response) can be developed based on existing technology. Partner activity has already been identified in WP 2.9.8.

f. **WP2.9.6 – Smart AFCS actuators**

The feasibility of controlling the wing flaps with serial actuators having limited authority, for gust loads alleviation and ride comfort will be investigated. Concerning the tail surfaces, artificial stabilisation obtained with fast serial actuators will be considered as a possible option to reduce the size of fixed surfaces and save some structural weight.

g. **WP2.9.7 – Follow-Up of On-Board Systems Testing**

The teams and partners developing or procuring actuators will help defining, preparing and following specific tests on the flight control system bench. Further, they will remain involved during the flight demonstrator ground testing and flight testing phases.

h. **WP2.9.8 – Flight Control Actuators**

This W2 Partner Topic FRC2.9-1 in Actuators is in connection with WP 2.9.2, 2.9.4 & 2.9.5.
III. High level WBS

Figure 8.21 – WP2.9 High-Level WBS

IV. Added value versus state-of-the-art

The selection or development of actuators based on state-of-the-art EMA technologies will enable realization of advanced rotorcraft flight control functions which are developed in WP9.12, with beneficial impact on weight.
### WP2.9 - Actuators

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**WP 2.9.1** Lifting Rotor Actuators

**WP 2.9.2** Propeller Flight Control Actuators

**WP 2.9.3** Hydraulic generation

**WP 2.9.4** Pitch & Yaw Trim Actuators

**WP 2.9.5** Wing Flap Actuators

**WP 2.9.6** Smart AFCS Actuators

**WP 2.9.7** Follow-Up of On-Board Systems Testing

**WP 2.9.8** Flight control actuators

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### V. Partnerships

Calls for Proposals will be launched for further development or adaption of actuators already investigated in Clean Sky SGO or other research programs. It is expected that Members or Partners participating in Clean Sky technology developments will apply and be successful for continuation of their activities toward a higher readiness level, and that new partners proposing efficient solutions will also apply and be selected.

### VI. Schedule

The table below displays the TRL (Technology Readiness Level) for each activity, along with the years 2014 to 2020.
8.7.19 Avionics & Sensors WP2.10

I. Relevance and technical objectives

Ideally, a compound rotorcraft should be operated much like a conventional helicopter, seen by the crew simply as a faster, more efficient and more comfortable performer. The crew should ignore the additional vehicle complexity and would have to face the same work load as for a modern helicopter. In order to approach this ideal objective with the LifeRCraft demonstrator, the avionics have to be somehow adapted while relying as much as possible on existing hardware and software in order to minimize the impact on weight and cost efficiency.

II. Setup and activities

a. WP 2.10.1 General Specification

The specification of demonstrator avionics and sensors will be based on general mission requirements defined in WP2.1.1 and specific sensors as required to monitor the vehicle subsystems (WP2.2 to WP2.8). The specification will take in due account some constraints from existing equipment being re-employed although not perfectly fit for the flight demonstrator needs (for the sake of project cost and schedule control).

b. WP 2.10.2 Vehicle & Engine Monitoring System Adaptation

The VEMS will be modified to accommodate the additional input parameters to be monitored such as the torque on propeller shafts, flap position, rotor bending moment, control surface positions, etc. The VEMS software needs to be fully revisited in order to protect all critical vehicle components from exceeding their safe operating envelope while providing the pilot with clear and simple information, through the First Limit Indicator and other display pages.

c. WP 2.10.3 Additional Sensors

The additional sensors needed for the VEMS will be specified, procured and installed. In addition, numerous other sensors will be required for acquisition of experimental data on the demonstrator in order to monitor strains, temperatures, pressures, etc. to be analysed by the test crew and engineers on ground.

d. WP2.10.4 Display & HMI Adaptation

Only few modifications are expected on cockpit displays, computers and software besides the VEMS. The longitudinal attitude in hover, take-off and landing varies much less for a compound rotorcraft than for a conventional helicopter thanks to the use of propeller thrust instead of rotor flapping to control longitudinal accelerations; as a consequence, there could some freedom to redesign the dashboard for HMI adaptation securing the best field of vision for the pilot taking into account a fuselage attitude closer to the flight trajectory.

e. WP2.10.5 Installation Design & Realisation

Once the airframe geometry and the positions of displays, computers and sensors are defined, the detailed design of the installation with the routing of harnesses will be defined and realized. The delivery of the full system is needed for the flight demonstrator assembly. Nonetheless, displays with the modified pilot interface will be required earlier, for the piloted simulation tests (WP2.12.5) and for the flight control system bench (WP2.10.1).
f. **WP 2.10.6 – Follow-Up of On-Board Systems Testing**

The teams and partners in charge of avionics design will help defining, preparing and following specific tests on the flight simulator and flight control system bench. Further, they will remain involved during the flight demonstrator ground testing and flight testing phases.

III. **High level WBS**

IV. **Added value versus state-of-the-art**

The adaptation of avionics, in particular the sensors and VEMS, will ensure the same level of safety and pilot workload with this innovative rotorcraft configuration than with a conventional helicopter despite the higher number of parameters to be monitored and the extended flight domain. The display panel can be reorganized to ensure best vision ergonomics for the pilot.
**V. Partnerships**

Support of avionic manufacturers may be required to adapt some equipment and/or to update the software if needed to accommodate the additional or changed parameters.

**VI. Schedule**

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<tr>
<td>WP 2.10.4 Display &amp; MMI Adaptation</td>
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<tr>
<td>WP 2.10.6 Follow-Up of On-Board Systems Testing</td>
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</tbody>
</table>
8.7.20  Cabin & Mission Equipment – WP2.11

I.  Relevance and technical objectives

Requirements for low aerodynamic drag translate into the need to shape the fuselage with a slim cross section and streamlined profile whilst it has to preserve the fundamental helicopter functionalities. This calls for securing easy cabin access for special emergency services such medical evacuation with stretchers or hoist operation with crew or wounded persons on the hook; such access being protected from any interference with propeller blades or slipstream. The cabin layout, windows, access doors, and the internal mission equipment installation has thus to be reconsidered with a vision quite different from that of conventional helicopter.

Innovation is needed to maintain cabin comfort in terms of noise and vibration and thermal comfort. Indeed the high cruise speed and proximity of propellers represents medium/high frequency noise sources particularly annoying for the crew and passengers while cabin paneling using conventional sandwich materials might be found insufficient for soundproofing and/or too heavy. Perfect sealing of doors without any gap or air leak has to be ensured despite the unpressurized cabin and structural deformation throughout the flight domain, in order to prevent whistling sounds and external air penetration.

The detailed configuration of the demonstrator cabin and mission systems will be established during the preliminary design phase considering the specific constraints and its description cannot be delivered before reaching that stage. [TF34]

II.  Setup and activities

a.  WP2.11.1 - Cabin Layout Studies & Specification

These studies can start only after the general airframe architecture and structural concepts are frozen (end of WP2.1). Based on prediction acoustic sources and thermal balance, specifications for the wall insulation and soundproofing and cabin air system will be defined.

b.  WP2.11.2 - Insulation & Noise Control

Weight-efficient solutions for insulation and sound proofing will be adapted using background from previous R&T programmes performed at EU and national level. Usage of bio-fibres as developed in CS-EDA will also be considered. Active noise control to eliminate propeller noise can be envisaged based on existing know-how. The WP2.11.2.2 - Interior noise control includes the W2 Partner Topic FRC2.11.1.

c.  WP2.11.3 - Air Control & Distribution System

It is expected that an existing Air Control System (ACS) could meet the need for the demonstrator. However, the air distribution has to be customised for the new cabin dimensions and hose routing will be adapted to the airframe structural constraints.

d.  WP2.11.4 - Doors & Cabin Access

The cabin doors will be designed and checked for deformation under flight loads and air tightness. Opening kinematics (whether hinged or articulated or sliding mechanism), locking system and handles have to be designed for smooth and reliable operation and should not offer any significant gap, excrescence, or surface irregularity which may spoil the aerodynamic flow and increase drag in flight. Weight appears as a crucial concern also for doors.
The WP2.11.4.2 – Equipment for cabin access includes the W2 Partner Topic FRC2.11-2.

e. **WP2.11.5 - Installation of Specific Mission Equipment**

The installation of a rescue hoist has to allow full retraction inside the cabin or inside the airframe profile in order to preserve the aerodynamic cleanliness in cruise; it should nevertheless offer the same functionality as an externally protruding hoist for rescue operations and not create an obstacle for access to the cabin when not deployed.

f. **WP2.11.6 - Follow-Up of On-Board Systems Testing**

The teams and partners in charge of cabin systems and mission equipment will help defining, preparing and following specific tests on the airframe mock-up (WP2.2.4). Further, they will remain involved during the flight demonstrator ground testing and flight testing phases.

### III. High level WBS

![High level WBS diagram](image)

**WP 2 IADP Rotorcraft**

- **LifeRCraft Demo**
- **WP 2.11 Cabin & Mission Equipment**
  - **WP 2.11.1** Cabin Layout: Studies & Specification
  - **WP 2.11.2** Insulation & Noise Control
  - **WP 2.11.3** Air Control & Distribution System
  - **WP 2.11.4** Doors & Cabin Access
  - **WP 2.11.5** Installation of Specific Mission Equipment
  - **WP 2.11.6** Follow-Up of On-Board Systems Testing

### IV. Added value versus state-of-the-art

Ability to offer helicopter-like or better cabin comfort and cabin functionalities for transport or rescue or medical evacuation with an optimised cabin architecture, with limited or no weight penalty.
### Technologies / Activities

Cabin arrangement and installation of mission equipment to be designed based on specific airframe architecture constraints; Design of cabin insulation for acoustic & thermal comfort; Installation of air conditioning and heating system (no pressurization) COTS for all equipment. Air conditioning ground test (using mock-up)

### Results / Added value

SAR and EMS mission efficiency with architecture different from conventional helicopter; Cabin comfort in high speed rotorcraft with limited/no weight penalty

### Background

For interior noise & air condition: FACE TP, Nat. R&I projects

### Lead Actors / Key Contributors

AHG, suppliers

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#### V. Partnerships

- Research/Industrial lab(s) for collaboration on advanced acoustic and thermal cabin treatments with weight efficient materials (including bio-fibres) equipped with suitable test facilities;
- Research/Industrial lab(s) for collaboration on active propeller noise control with suitable test facilities.

#### VI. Schedule

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2014 Clean Sky 2 Joint Technical Programme (V4) – Proprietary Information subject to Confidentiality Agreements
8.7.21  Flight Control, Guidance, Navigation – WP2.12

I.  Relevance and technical objectives

Ideally, a compound rotorcraft should be operated much like a conventional helicopter, seen by the crew simply as a faster, more efficient and more comfortable performer. The crew could ignore the additional vehicle complexity and would have to face the same work load. In order to approach this ideal objective with the LifeRCraft demonstrator, the subsystems performing flight control, guidance and navigation functions have to be substantially adapted while relying as much as possible on existing hardware and software in order to minimize the impact on weight and cost efficiency.

The detailed configuration of the demonstrator FCS/AFCS, guidance and navigation systems will be established during the preliminary design phase considering the specific constraints and its description cannot be delivered before reaching that stage.[TF35]

II.  Setup and activities

a.  WP2.12.1 - Flight Control System for Compound Rotorcraft

Several options are open for the Flight Control and Automatic Flight Control Systems. The basic and simplest one would retain the same architecture as the X3 test bed which is essentially similar to that of a conventional helicopter hydro-mechanical system with the addition of manually controlled trim actuators for the additional hybridization control inputs (tail surface controls, flaps, collective propeller pitch).

More advanced options would involve the automation of one, several or all additional trim actuators in order to simplify the pilot’s work and/or to optimise aerodynamic performance in the full flight envelope and/or minimise dynamic loads on rotor components and/or minimise noise emission.

In addition, it can be envisaged to introduce some additional dynamic control functions in order to minimize the gust response while flying fast in a turbulent atmosphere or even further, to take advantage of such stabilization functions and to reduce the size and weight of fixed tail surfaces.

Finally, the most advanced option would be to replace the long and complex propeller pitch control linkages by a Fly-by-Wire system that would open a full range of new capabilities for flight of compound rotorcraft. On the other hand, the development of such a Fly-by-Wire system may not be compatible with the project schedule and cost envelope.

The first step in this work package will consequently consist in carefully defining the FCS architecture and deriving the specifications for its subsystems. Most of the FCS and AFCS components will use COTS hardware with some adaptation, at least for the basic configuration. The software will need to be substantially revisited.

b.  WP2.12.2 - Smart Automatic Flight Control for Fuel Saving

The auto-trim function to be developed for fuel saving will involve the automatic control of tail trim actuators, propeller pitch collective and flaps according to the flight conditions.

Additionally, the feasibility of wing flaps control with faster response actuators, for gust loads alleviation and ride comfort will be investigated.

Artificial stabilisation obtained with fast tail actuators will be considered as another possible option to reduce the size of fixed surfaces and save some structural weight, but will not be realised on the demonstrator (not compatible with airframe realization schedule).

The WP2.12.2.2 – Flight Profile for fuel saving includes the W1 Partner Topic FRC2.12-1.
c. **WP2.12.3 - Environment-Friendly Flight Procedures**

Based result obtained in CS-GRC5 (TP3), the consequence of the LifeRCraft specific performance and additional control inputs on noise abatement procedures will be examined, in a first step by analytical prediction and, after flight testing (WP2.12.6), revised using a measured acoustic database. Compatibility and consistency of these specific flight procedures with SESAR Concepts of Operation and ATM rules will be maintained through continued collaboration with competent laboratories and organisations involved in SESAR activities. The WP2.12.3.2 – Noise abatement flight procedures includes the W1 Partner Topic FRC2.12-2.

d. **WP2.12.4 - Guidance System for Environment-Friendly Flight**

The guidance systems for noise abatement as developed in CS-GRC5 TP6 and 7 (resp. for VFR ad IFR) will be adapted for verification in piloted simulation and, if feasible with the avionic suite available, installed on the demonstrator for flight trials. Similarly, new system functionalities aimed at supporting the crew for fuel-efficient flight trajectories will be investigated, further to earlier studies at Eurocopter and Partners.

e. **WP2.12.5 - Piloted Simulation**

Systems under development in WP2.12.1, 2.12.2 and 2.12.4 will be repeatedly evaluated by test crews in a piloted simulator and the simulation test results will support the design throughout the development process.

a. **WP2.12.6 – FCS-AFCS Integration Tests and Follow-Up of LifeRCraft Demonstrator Tests**

For the Flight Control System (FCS) including the autopilot (AFCS), integration tests will be performed on a dedicated bench which will incorporate the pilot controls, part of the cockpit dashboard, AFCS computers and relevant actual/physical actuators, simulated sensors and the vehicle flight model to close the loop. These tests will allow validating and fine tuning the control laws in normal and degraded modes corresponding to the failure scenarios. Individual actuator and sensor tests, as far as required, will be performed in WP2.9 and 2.10.

This WP will start with the preparation of rig as soon as equipment prototypes are available and the tests will be completed at least three months prior delivery of flightworthy equipment in order to allow correcting any problem that may be uncovered during these tests.

The teams and partners in charge of FCS/GUID/NAV systems design will further be strongly involved during the flight demonstrator ground testing and flight testing phases.
III. High level WBS

Figure 8.24 – WP2.12 High-Level WBS
IV. **Added value versus state-of-the-art**

- Smart FCS exploiting additional degrees of freedom for best vehicle L/De, hence performance improvement, fuel burn reduction and range extension (TRL 6);
- Noise impact and fuel burn reduction through flight procedures and guidance system adapted to specific missions (TRL 4-5).

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<th>WP L1</th>
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<th>Technologies / Activities</th>
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<th>Background</th>
<th>Lead Actors / Key Contributors</th>
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| WP2.12 |       | Flight Control, Guidance & Navigation Systems | Combination of OTS systems, with substantial upgrades or mods (mainly software):  
- FCS: additional controls includ.
  Possibly FbW prop control, compounding controls across flight domain with back-up modes.  
- AFCS: autotrim function with optimized control mix across flight domain. Optionally, active control of tail surfaces;  
- NAV: low noise guidance mode to be adapted and optimised for LifeRCraft configuration  
Piloted simulation to validate handling qualities and control laws | Same safety level and pilot workload than for conventional helicopter in similar missions;  
Active control of tail may allow reducing area of fixed surfaces hence structural weight, contributing to low empty weight fraction.  
Smart flight control exploiting additional degrees of freedom for best vehicle L/De, hence performance improvement, fuel burn reduction and range extension;  
Noise impact & fuel burn reduction. | X3 test bed project  
CS GRCS-TP3, TP6, TP7 | AHG, equipment manufacturer,  
Research Institutes or labs, SESAR actors |
V. Partnerships

Research Institutes or laboratories having the expertise either concerning rotorcraft noise prediction suitable to predict noise emission of a compound rotorcraft, or concerning ATM and navigation optimised for fuel savings.

VI. Schedule

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<td>WP 2.12.2 Smart Automatic Flight Control for Fuel Saving</td>
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<td>WP 2.12.3 Environment-Friendly Flight Procedures</td>
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<td>WP 2.12.5 Piloted Simulation</td>
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<td>WP 2.12.6 FCS-AFCS Integration Tests and Follow-Up of LifeRCraft Demonstrator</td>
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8.7.22 Validation, Verification, Demonstration – WP2.13

I. Relevance and technical objectives

All technology and subsystem development activities converge toward the final integration and demonstration which materialize in the V&V and Demonstration activities. The technology maturation at TRL6 can only be achieved through conduction and successful completion of this WP. Compliance with high level technical objectives as reminded below can only be assessed and substantiated at this stage with the full integrated vehicle:

- Peak fineness $L/D_e$;
- Empty weight fraction;
- Maximum operational cruise speed;
- Noise level (in EPNdB) and acoustic footprint;
- Fuel consumption and CO$_2$ emission.

Based these measured data, the operational capabilities of potential future products can be confidently extrapolated and expressed in terms of transport efficiency and overall mission effectiveness: speed, range, payload, cabin functionality to be compared with initial objectives and state-of-art for different rotorcraft and aircraft configurations in order to assess the market potential.

II. Setup and activities

This WP gathers the following 2nd level work packages to be conducted in sequence after delivery of components and subsystems from WP2.2 to WP2.12:

a. WP 2.13.1 Rotor System Rig

All main rotating components provided by WPs 2.4 and 2.5 (Lifting rotor and propellers) will be tested on a large ground rotor system rig before the demonstrator first flights. These components will be installed on a robust supporting structure and driven by a suitable ground mechanical power source. If the further analyses indicate that it could contribute to reduce significantly the risk for the flying demonstration phase some components of the mechanical drive system (WP 2.6: e.g. propeller transmission), flight control actuators (WP2.9) and structural components (e.g. non-flightworthy wing) will be also installed on this rig to insure the best representativity of these rig tests.

The main purpose of these rig tests is to:

- Optimize and validate the configuration to be tested in flight;
- Determine characteristics, particularly rotor and propeller performance before flight.

Tests will start as soon as prototypes of all necessary components are available and will continue while the flight demonstrator is being assembled.
b. **WP 2.13.2 Flight Demonstrator Assembly**

Availability of all parts and equipment delivered by WPs 2.2, 2.3 and by the Airframe ITD work packages HEV1.1 and HVE 4.1 and of the mechanical parts provided by WPs 2.4, 2.5, 2.6 and 2.7 will determine the date to start the flight demonstrator assembly. The assembly process for an experimental rotorcraft requires a flexible organization in order to mitigate unplanned events such as delayed provision of some components and systems. The assembly can be completed in six months until roll-out.

c. **WP 2.13.3 Flight Demonstrator Ground & Flight Testing**

After roll-out (WP2.13.3), the demonstrator will be submitted to ground tests. Completing the dynamic identification test (‘shake test’) is one of the first and most crucial milestone for any rotorcraft as even small deviations between actual and predicted vibration modes may have a severe impact on in-flight behavior that may require implementation of corrective actions on the airframe, suspension and component junctions in order to mitigate risks of resonance or coupling instabilities (e.g. ground resonance). Ground testing will further be advanced with the verification of all on-board systems (engines off). Then ground rotations will be performed with engines and kinematic chain running. Successful ground tests will allow passing the flight test review and obtaining the permit-to-fly: milestone FT+PtF.

The flight testing will start following the logical sequence: flight domain exploration, airloads and stress qualification, noise & vibration qualification, handling qualities & pilotability testing, performance tests, on-board systems, and finally some operational demonstration, including noise impact evaluation, with and w/o the low noise approach mode.

[The TF37] demonstration of mobility and operational flexibility achievable with the compound rotorcraft concept will not be elaborated directly in flight as the non-certified demonstrator might not be allowed to perform complete missions carrying non test-qualified personnel nor to fly over densely populated areas. Instead, it will undergo a performance measurement campaign sufficient to identify and calibrate the performance model in the required flight envelope. Then demonstrations of the critical mission elements which are take-off, approaches, loading and unloading, precision hovering with hoist operations, etc. will be performed. With all the results, the target missions can be simulated accurately and the demonstration outcome confidently assessed as part of the TE process.

d. **WP 2.13.4 Project synthesis**

In the last three months, project results from specifications and early technology developments to conclusions and lessons learnt from demonstrator flight tests will be collected in general synthesis documents with some presentations for further dissemination purpose. The project final results will be provided to WP2.1.6 and further to WP0.3 in order to update the conceptual compound rotorcraft model and to allow the Technology Evaluator to perform its own impact assessment.
III. High level WBS

![High level WBS diagram]

Figure 8.25 – WP2.13 High-Level WBS

IV. Added value versus state-of-the-art

Successful completion of WP2.13.1 and 2.13.2 is deemed sufficient to pass a TRL4 gate for the compound rotorcraft as an integrated vehicle incorporating with all new components and critical technologies. By the time the permit-to-fly is obtained, TRL5 will be reached. Finally, TRL6 will be passed pending upon successful completion of the demonstrator testing.

Based on conclusions reached in WP2.13.5, the exploitation potential taking into account environmental and mobility benefits along with industry enhanced competitive position may be reassessed and hopefully confirmed.
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<td>Rotor system rig</td>
<td>Rotor and propellers assembled on a mechanical rig; Functional tests; Endurance tests.</td>
<td>Detection &amp; correction of rotor and propeller problem not visible at component level, Rotor and propeller performance measurement to be used for flight results analysis; Success conditioning Permit to Fly.</td>
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<td>2.13.2</td>
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<td>Flight Demonstrator Assembly</td>
<td>Flight demonstrator assembly integrating components delivered by WP2 and ITD Airframe</td>
<td>Flight demonstrator</td>
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<td>AHG with support of Core partners and partners</td>
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<td>2.13.3</td>
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<td>Demonstrator Ground &amp; Flight Tests</td>
<td>MMI test; Installation of flight test equipment (sensors, data acquisition); Dynamic identification test; Pre-flight tests; Flight domain exploration; Airloads and stress qualification; Noise &amp; vibration qualification; Handling qualities, pilotability; Performance tests; Operational demonstration, including noise impact evaluation, with and w/o low noise approach mode;</td>
<td>TRL6 for LifeRCraft concept integrating all critical technologies;</td>
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<td>AHG, core partners, partners</td>
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V. Partnerships
Throughout the V&V and demonstration phase, the OEM will need the continued follow-on and support of Core Partners and Partners involved in the development of components and subsystems as some modifications may be mandatory in order to complete the demonstration in case on specific problems uncovered during WP 2.13.

### VI. Schedule

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8.7.23 Synthesis of LifeRCraft added value with respect to H2020 targets

Thanks to the integration of technologies already matured in Clean Sky and to the provision of alternate back-up solutions for the less mature ones, the compound rotorcraft concept which benefits from earlier substantial industry investment with the X³ test bed can be confidently raised to TRL6 at aircraft system level within a relatively shortly period: less than 6 years. With the major technical and industrial risks lifted, this will allow exploitation to follow suite swiftly with a product development. Commercial deployment could then be expected in the years 2023-24, with rapid return in terms of rotorcraft market shares (more than 50% for civil/parapublic segments) and top-qualified work force being maintained and extended in homeland Europe both in the industry and with the operators.

No other R&I instrument than the Clean Sky JTI can provide a suitable framework to bridge the gap between industrial research and product innovation.
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9 Airframe ITD

9.1 Going beyond Clean Sky

Aircraft level objectives of greening, mobility improvement, fulfillment of future market requirements and contribution to growth cannot be met without strong progress on the airframe. On greening the very ambitious CO₂ and noise reduction targets of FP2050 will typically rely for between 30 and may be up to 50% on progress on airframe. Improvements on mobility and agility, also integral part of the FP 2050 vision, are a shared objective between airframe and systems.

Within Clean Sky strong progress towards the 2020 targets will have been obtained (estimated at 75% of the relevant part of the ACARE goals). Nevertheless, a step beyond for the airframe novel technologies integration and advanced aircraft configuration maturation is required to achieve a readiness suitable for an insertion into a next generation of product, and to pave the way to further improvements toward the second wave of targets set by FP2050:

- The SFWA ITD will have demonstrated a more efficient wing with natural laminarity, optimized control surfaces and control systems. Also novel engine integration strategies will have been derived and tested. However the applicability is limited in scope (focused on short range / low wing sweep / lower speeds) and further quantitative progresses are required to fully reach the 2020 target and further progress towards the 2050 ones;
- The Systems (EDS) part of the Eco-Design ITD will deliver a complete set of energetic, electrical & thermal models, tuned against an electrical test bench (Copper® Bird) and a thermal test bench. But further progress is required on aircraft integration of electrical systems in airframe, in consistency with the capitalization of the models through global aircraft architecture analysis. The Airframe (EDA) part of the Eco-Design ITD will have developed a set of more environmental friendly technologies, whose benefits once integrated in a platform, will be assessed using an aeronautical Life Cycle Analysis (LCA) tool, validating then some Eco-Design guidelines. A further validation of the process to escalate at the aircraft level the LCA is required. Further development of new the eco-friendly technologies highlighted along the EDA activities will be necessary to improve the aircraft environmental impact, in line with the Clean Sky Eco-Design guidelines.
9.2 Challenges to be tackled for Airframe ITD in the Horizon 2020 period

Airframe and aircraft concepts are fundamental drivers of the air system performances. The Airframe ITD will deliver decisive technology innovations that all-embrace the wide range of the European aeronautic industry’s portfolio, i.e. small transport aircraft, business aircraft, regional aircraft, large passenger aircraft and rotorcraft. Stressed by mounting competition from existing and new entrants on virtually all segments, the European aeronautics industry will maintain its market leadership only thanks to innovations and affordable product performances.

The Airframe ITD is a vital platform to gather the European airframers and the aero-structure supply chain, the systems suppliers and the academic & research networks on key enabling demonstrations, to serve future generation of European aircraft products. This will bring key support to the European environmental, mobility and industrial leadership objectives targeted in the different IADPs. More precisely the Airframe ITD will:

- Reduce aviation environmental footprint through product performance improvements (drag, weight, versatility) and an eco-friendly life cycle including significant recyclability increase as well as optimized material streams;
- Help to improve mobility and decrease congestion by supporting vehicle developments that improve time efficiency and agility;
- Address future market needs with product differentiators making travel greener, more efficient and more pleasant, easily adaptable to typical passengers profile reducing stress level and making aircraft globally more cost efficient;
- Set an active collaboration with the aircraft OEM and the large aero-structure supply chain around integrated platforms, focused on key essentials, shared achievements. It will attract European research and testing infrastructures and capabilities toward a joint innovation effort in line with future market aspirations;
- Contribute to European growth and to the preservation of highly skilled jobs thanks to advanced production processes and more efficient design, validation and certification processes.
9.3 The Role of the Airframe ITD

The Airframe ITD will support technology de-risking at major system level, to be further integrated in the vehicle integrated demonstrators. Globally speaking, the Airframe ITD targets to bring novel technologies up to TRL6 at airframe level i.e. mature to be integrated and tested at the global aircraft level, typically throughout the IADP flight tests.

With respect to this objective, the Airframe ITD encompasses a consistent set of major demonstrators, with the following demonstration options under consideration:

- Ground demonstration at a representative scale of the airframe component;
- Flight demonstration of a modified platform, incorporating the new system for demonstration in representative flight condition;
- Sub-scale flying demonstrator.

As delivering matured technologies as well as key airframe components to be further integrated at global aircraft level in IADPs demonstrators, the Airframe ITD is one of the enablers of the different IADPs. Nevertheless, it will encompass a wider range of airframe technologies, and mature these, with two key outcomes:

- Complement the technology portfolio of the air vehicle concepts addressed in the IADPs, in particular with next generation solutions at TRL 6 level;
- Insert key enabling technologies specific to other aircraft applications such as business jets, in a systematic approach geared towards vehicle level optimization. Technological challenges linked to these applications include for example innovative wing concepts, and unconventional fuselage configurations including novel propulsion integration solutions. These technologies for a longer term insertion will be brought up to a maximum of TRL 5.

Therefore, activities are structured around technology streams that will make the best use of synergies across the wide product range targeted by Clean Sky 2 (small transport aircraft, business aircraft, regional aircraft, large passenger aircraft, and rotorcraft) in a cross-cutting manner. The technology streams will allow undertaking the significant number of technology developments within a global consistent strategy orientated toward their insertion at integrated level into key large airframe systems components. It does not deliver set of stand-alone technologies, but demonstration of the technologies ready to be implemented into complex system and to actually contribute to the system global performances.

Integration issues within a global aircraft concept will be addressed in interaction with relevant aircraft concepts design undertaken in the IADPs, and interfacing issues with engines, system and cabin components will be managed in interaction with the relevant ITD throughout different aircraft concept analysis dedicated to the different product segments. Such will also cover the interfacing with the TE.
9.4 Setup of the Airframe ITD

9.4.1 Implementation

Strong progress is required on the most complex and challenging requirements on new vehicle integration to fully meet the ACARE 2020 objective, and to progress towards the 2050 goals. To make this possible, key directions of progress are as follows:

- **Introducing innovative/disruptive configurations** with a step change in terms of efficiency: conventional aircraft architectures have been primarily driven by component characteristics, requirements and their performance (e.g. pod engine integration for undisturbed air ingestion, etc.). Progress on components and on the understanding of their integration requirements makes new, more efficient configurations possible. One example is buried engines and cabin architecture with integrated systems more human centered.

  Investigation and demonstration of associated progress in nacelle is also key to support ruptures in novel engine integration configurations.

  Progress on certification processes and associated modelling capacities, focused on configurations of interest, will be a key enabler.

  The airframe ITD will develop and ground test innovative elements, and interface with the relevant IADPs for flight testing.

- **Developing more efficient wings**: the Smart Fixed Wing project in Clean Sky has provided important progress. A further step change can be obtained combining:
  - Weight-optimized use of composites on an aero-optimized wing;
  - Smart usage of control systems to better optimize the global wing design;
  - Demonstration of cost effective production of laminar wings, and the consolidation of hybrid laminar flow technology, to be flight tested within the Large Passenger Aircraft IADP;
  - Demonstration of low cost production processes of lightweight wing;
  - Demonstration of the aero efficiency of low cost wings, to be flight tested with the Regional Aircraft IADP and also preparing the Rotorcraft IADP.

- **Developing fuselages with optimized usage of volume and minimized weight, cost and environmental impact**:

  Step changes in efficiency and environmental impact are expected from – optimized (non-circular) shapes of fuselage – optimized structure for a cockpit – optimized use of metallic and composite materials – new integration of windows and of systems – new design oriented to production eco-efficiency optimization and recycling techniques, all of which will be ground tested at full scale.

  Taking full advantage of the fuselage re-thinking, cabin concepts will be reviewed and ground tested, to create the best travelling environment and to reach new level of passenger comfort, increasing the global efficiency of the mobility services bring by aviation.

- A complementary path will be to better optimize the design of the “equipped airframe” by developing highly integrated structures, i.e. thinking about the structural design with full consideration of equipment installation & integration requirements as a global optimization parameter. Highly integrated structure components will be ground tested and, in some case, further integrated in the Regional Aircraft IADP. Developments will also enable the dense integration of the new generation of equipment’s, in particular in the view of the more electrical aircraft.
Ensuring the **Environmental & Production efficiency**, sustaining the competitively and efficiency of the manufacturing processes to secure jobs in Europe, while significantly contributing to the reduction of the aircraft environmental footprint with the global Life Cycle perspective. As such, the Airframe ITD is one key implementation pillar of the Eco-Design transverse activity.

Airframe ITD technical directions will not only cover concepts and product technologies but also manufacturing and assembly techniques, modeling and other enabling capabilities, bringing significant improvements to European aeronautic industry efficiency in design and development, and high productivity manufacturing.

Analysis of technology insertion into future aircraft concepts will be done in a transversally to the technology streams, achieving the **Interfaces & Cross-interaction Management** within the IADPs and ITDs for the different categories of transport systems: Large passenger Aircraft, Regional Aircraft, Rotorcraft, Business Jet and Small transport Aircraft.

All of these Directions of Progress will be enabled throughout the foreseen execution of 9 major Technology Streams:

- **Innovative Aircraft Architecture**, to investigate some radical transformations of the aircraft architecture;
- **Advanced Laminarity**, as a key technological path to further progress on drag reduction, to be applied to major drag contributors: nacelle and wing;
- **High Speed Airframe**, to focus on the fuselage & wing step changes enabling better aircraft performances and quality of the delivered mobility service, with reduced fuel consumption and no compromise on overall aircraft capabilities (such as low speed abilities & versatility);
- **Novel Control**, to introduce innovative control systems & strategies to gain in overall aircraft efficiency;
- **Novel Travel Experience**, to investigate new cabins including layout and passenger oriented equipment and systems.
- **Next Generation Optimized Wing Boxes**, leading to progress on the aero-efficiency and the ground testing of innovative wing structures;
- **Optimized High Lift Configurations**, to progress on the aero-efficiency of wing, engine mounting & nacelle integration for aircraft who needs to serve small, local airports thanks to excellent field performances;
- **Advanced Integrated Structures**, to optimize the integration of systems in the airframe along with the validation of important structural advances and develop and to make progress on the production efficiency and manufacturing of structures;
- **Advanced Fuselage** to introduce innovation in fuselage shapes and structures, including cockpit & cabins.

Due to the large scope of technologies undertaken by the Airframe ITD, addressing the full range of aeronautical portfolio (Large passenger Aircraft, Regional Aircraft, Rotorcraft, Business Jet and Small transport Aircraft) and the diversity of technology paths and application objectives, the above technological developments and demonstrations are structured around 2 major Activity Lines, allowing to better focus the integrated demonstrations on a consistent core set of user requirements, and, when appropriate, better serve the respective IADPs:

- **Activity Line 1**: Demonstration of airframe technologies focused towards **High Performance & Energy Efficiency** (HPE);
- **Activity Line 2**: Demonstration of airframe technologies focused toward **High Versatility and Cost Efficiency** (HVC).

For the sake of the optimization of the modus operandi of the work execution, and of the ITD management efficient, each Activity Line will have its own management and contractual structure and governance, each with a
Leader and a Co-Leader. A proper interfacing between the 2 Activity Lines will be ensured by the 2 management groups, with periodic exchange forums, information exchanges, to harmonize work plan, enhance the synergies and complementarities. Joint reporting forums will be organised.

The figure here below shows the 10 foreseen Technology Streams with their structure into 2 Activity Lines, basis of the Level Work Break Down structure of the Airframe ITD.
Figure 9.1 - High level WBS of Airframe ITD (Level 1)
### 9.4.2 Progress Path & Expected Impact

The Technology & Demonstration Streams above, and their expected impact, are summarized in the table below:

<table>
<thead>
<tr>
<th>Technology Stream</th>
<th>Progress path versus State-of-the-Art enabled through <em>Clean Sky 2</em></th>
<th>Serving the societal challenges</th>
<th>Lead Actors / Key Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovative A/C Architecture</td>
<td>Conventional aircraft architectures have been primarily driven by component characteristics, requirements and performances (e.g. pod engine integration for undisturbed air ingestion, etc.); Progress on components and on the understanding of their integration requirements makes new more efficient configurations possible. Identically, radical change in major component such as with the CROR engine leads to a complete re-thinking of the aircraft configuration and the propulsion integration. Eco-Design related information technology.</td>
<td>Resource Efficiency: -10% to -15% CO₂, -5 to -10 EPNdB  Industrial Leadership: Product differentiator from non-European competition:  - Fuel efficiency,  - Weight and size reduction  Reduced Time to Market including certification  Improved Life Cycle cost design.  Enhanced Mobility: Operation in dense environment:  - Noise containment  - Altitude flexibility  - Adapted size  Access to secondary airports:  - Enhanced take-off &amp; landing performances  - Minimized infrastructure requirements  Time efficiency: improved Mach number robustness  Cost effective transport (reduction of DOC including reduction of certification cost)</td>
<td>Airbus, Dassault, FhG, Engine Supplier, Research Institute, PLM &amp; engineering software provider,</td>
</tr>
<tr>
<td>Technology Stream</td>
<td>Progress path versus State-of-the-Art enabled through <em>Clean Sky 2</em></td>
<td>Serving the societal challenges</td>
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</tr>
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| **Advanced Laminarity** | Laminar Flow is the aerodynamics technology with the highest drag reduction potential. Within *Clean Sky*, Natural laminarity of wing for $M=0.75$ aircrafts is under way to be demonstrated at large scale in major ground rigs and in flight. A critical additional issue to ensure its successful integration into next generation of product is to demonstrate the integration of all key elements of a low drag wing into a main wing structural concept that allows for a high rate industrial production at competitive effort. In term of performances, the next step is the increase of Mach number applicability (up to $M=0.85$ for long range applications) and more extensive applicability on the wing (e.g. inner wing). Laminarity Flow is also to be applied on nacelle, to overcome the drag effect from innovative turbofan engine solutions due to their substantial increase in Fan (respectively nacelle) diameters which could compromise the fuel burn improvements. | **Resource Efficiency**: -7 to -12% CO$_2$ **Industrial Leadership**: Product differentiator from non-European competition:  
- Fuel efficiency,  
- Weight reduction  
**Enhanced Mobility**: Production capacity in Europe of “too me” product  
Time efficiency: improved Mach number robustness (extended laminarity domain & applications); Cost effective transport (reduction of DOC by 4-8%). | Airbus, Dassault, CASA, SAAB Research Institute, University, Aero-Structure Industry, Engine Supplier |
### Domain: High Speed Airframe

Further to *Clean Sky* progress on wings, global aero structural optimizations are both possible and necessary, in particular in order to enable travelling time reduction while improving the global environmental balance of high speed. One aspect will be also to sustain/improve the low speed capabilities for an high speed design. Integration of aerodynamic and structure innovations for wing efficiency, demonstration of novel fuselage shapes and structures, rethinking of the forward fuselage/cockpit structure can lead to further progress on drag and weight in the frame of an optimized production process.

With progress on certification process and Eco-Design capabilities, evolutions in the design & production environment, will create favourable conditions to the coming out of ruptures in aircraft architecture.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Progress path enabled through <em>Clean Sky 2</em></th>
<th>Serving the societal challenges</th>
<th>Lead Actors / Key contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Speed Airframe</td>
<td>Further to <em>Clean Sky</em> progress on wings, global aero structural optimizations are both possible and necessary, in particular in order to enable travelling time reduction while improving the global environmental balance of high speed. One aspect will be also to sustain/improve the low speed capabilities for an high speed design. Integration of aerodynamic and structure innovations for wing efficiency, demonstration of novel fuselage shapes and structures, rethinking of the forward fuselage/cockpit structure can lead to further progress on drag and weight in the frame of an optimized production process.</td>
<td>- 10 to -15% CO₂ (through drag &amp; weight saving) Eco-compliant production; Low energy /Low resources production; Roadmap to full recyclability</td>
<td>- Product differentiator from non-European competition: Fuel efficiency, Weight reduction Competitive production in Europe (reduction of production cost, automation increase) Sustainable growth. Decreased production pollutions, recyclability Cost effective transport (reduction of DOC by 5-10%); Fast gate-to-gate transport and access to/ operations from secondary airports (low speed, weight, size saving, aerodynamic noise control); Quality of service: volume optimization &amp; internal noise reduction (fuselage) Safety : more efficient integration of crashworthiness requirements in fuselage design;</td>
</tr>
</tbody>
</table>
### Clean Sky 2 Joint Technology Initiative in Aeronautics

**Domain** | **Progress path enabled through Clean Sky 2** | **Serving the societal challenges** | **Lead Actors / Key contributors**
---|---|---|---
**Novel Control** | Linked to innovative wings and after bodies is the possibility of innovative control strategies both at global level (aircraft control, load, vibration & flutter control) and locally (control of instabilities). Direct gains on efficiency (weight, drag, agility) are expected; also innovative controls can be the enabler of more efficient configurations (e.g. tailless aircraft, flying wing, etc.). | -3 to -5% CO2 | Product differentiator from non-European competition:  
- Fuel efficiency,  
- Weight reduction  
Access to secondary airports: enhanced take-off & landing performances;  
Time efficiency: improved Mach number robustness;  
Safety:  
- New failure management architecture;  
- Better control of instabilities;  
- More efficient integration of loads limits in the wing design. | Dassault, Airbus, Research Institute, University Aero-Structure Industry, Equipement Supplier

**Novel Travel Experience (Advanced Cabins)** | Passenger cabins have not been addressed within Clean Sky and can bring improved passenger comfort and ergonomy, safety and services, but also significant fuel efficiency through weight reduction & ecological benefit considering Material, Processes and Resources (MPR), especially, with environmental friendly materials. | -3% CO2 (through weight saving) Eco materials | Product appeal: passenger comfort, no tiredness from travelling High level of in-flight services More eco-friendly processes | Travel seamless experience Mobility services into multi modal common platform Flight as productive time Safety: crashworthiness, cabin environmental quality, “well-being worthiness” | Dassault, Airbus, FhG, Cabin system provider, Research Institute, University, Material Provider, Equipment Supplier
<table>
<thead>
<tr>
<th>Segment</th>
<th>Resource Efficiency</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
<th>Contributors</th>
</tr>
</thead>
</table>
| **Next Generation Optimized Wing Box** | Structural improvements for wing, better use of composite materials and optimization of the wing efficiency will lead to further progress on drag, weight, for new, affordable and performing wing. | - 5 to -10% CO₂ (through drag & weight saving) | Product differentiator from non European competition:  
- Fuel efficiency,  
- weight reduction  
Competitive production in Europe (reduction of production cost, automation increase); available & competitive out of autoclave technologies & thermoplastic composites. | Cost effective transport (reduction of DOC by 4-8%); Affordable gate-to-gate transport; Reduced time to get on spot for emergency/life critical missions; Minimized infrastructure requirements for composite repair in remote areas, improved damage tolerance. | Dassault, CASA, EC, SAT Research Institute, University, Aero-Structure Industry, Material Provider |
| **Optimized High Lift Configurations** | Advanced aircraft configurations, more global aero structural optimizations and enhanced nacelle/engine integration will lead to further progress on drag and integration for high wing with large turbo propulsors. | - 5 to -10% CO₂ (through drag & weight saving) | Product differentiator from non European competition:  
- Fuel efficiency,  
- weight reduction  
| Affordable gate-to-gate transport  
Access to/ operations from secondary airports: enhanced take-off & landing performances | CASA Research Institute, University, Aero-Structure Industry, Nacelle suppliers, Engine suppliers |
| **Advanced Integrated Structures** | Improvements in the design and production processes will lead to more affordable, weight optimized structural components. A native, optimized integration of equipment & systems in the structural design will improve the final quality of airframe equipped with numerous novel equipments & systems, more and more power addicts. | -3 to -5% CO₂ (weight and energy saving) | Product differentiator from non European competition:  
- Fuel efficiency,  
- weight reduction  
Competitive Production in Europe, more automated metal & composite production  
Simplified architecture: improved maintainability  
Optimized maintenance (operation cost reduction), improved reliability, improved damage tolerance & minimized infrastructure  
Minimized requirements for repairs (operations in remote areas).  
Access to secondary airports: weight, size saving | Airbus, Alenia, CASA, SAT, SAAB Research Institute, University, Aero-Structure Industry, Material Provider, Equipment Supplier |
## Domain

### Low Speed A/C Advanced Fuselage

Innovations within *Clean Sky* have been limited to some major components or section with significant progress in particular on structural weight saving for the cockpit & forward fuselage barrel in GRA.

More global aero structural optimizations, and more efficient system integration, including propulsion integration, can lead to further progress on drag, weight and manufacturing processes.

### Serving the societal challenges

<table>
<thead>
<tr>
<th>Resource Efficiency</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
</tr>
</thead>
</table>
| Eco-compliant production | Product differentiator from non European competition:  
  - Fuel efficiency,  
  - weight reduction, size optimization  
  Competitive Production in Europe, more automated metal & composite production | Passenger comfort (volume, internal noise, etc.)  
Access to secondary airports: weight, size saving  
Cost effective transport (reduction of DOC by 4-8%) |

### Lead Actors / Key Contributors

- Alenia, CASA, EC, AW, SAT, FhG  
Research Institute, University, Aero-Structure Industry, Material Provider, Equipment Supplier

## Domain

### Management & Interfacing

Concept definition for alignment of the technology development and demonstration effort towards the defined objectives.

### Serving the societal challenges

<table>
<thead>
<tr>
<th>Resource Efficiency</th>
<th>Industrial Leadership</th>
<th>Enhanced Mobility</th>
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<tbody>
<tr>
<td>n/a</td>
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<td>n/a</td>
</tr>
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</table>

### Lead Actors

- Airbus, Alenia, AW, Dassault, CASA, EC, SAT, SAAB
9.4.3 Structure

At level 2 breakdown, each Technology Stream is composed into Work-Packages as shown on figure 9.2 hereafter.

Figure 9.2- Airframe ITD structure (Level 2 WBS)
9.5 Management Structure and Process

In the following sections are described the role and the implementation of the AIRFRAME ITD.

9.5.1 Interfaces Management

I. Management Structure

The here below picture depicts the role of the Airframe ITD and the architecture and interfacings with the IADPs, other ITDs and TE within the global integration strategy of Clean Sky 2.

The figure represents the main exchanges with other entities of Clean Sky 2, showing a strong coherence between ITDs and IADPs.

The ITD produce solutions demonstrated to a level allowing the maturation in the frame of the IADP demonstrators.

For example, TS B-2 Optimised high lift configuration will provide the solutions to be tested in flight in RA IADP. In a similar way, the WP All electrical wing will be used to select the solution to be tested in RA IADP. In fact, the plan of activities is organised in a way to allow feeding the IADPs with the ITDs WP.

The strong link between the IADPs and the technology developments performed within the TS WPs is insured by the WPs devoted to the Overall Aircraft Design and Configuration Management (OAD & CM: WP A-0.x and WP B-0.x as shown on figure 9.2 above).
II. Internal Management

The general management is represented on the following figure:

![Diagram of Airframe ITD Integrated Approach within Clean Sky 2]

The figure is focused on the example of the TS “Advanced Laminarity”. The basic principles behind the structure based on the TS WPs and OAD & CM WPs are:

- **Implementation of a strong ITD structure** including the Technology Streams to ensure:
  - Consistency in the technical objectives
  - Consistency in the technology field
  - Consistency in the application domain

- **Management of Interfaces & interactions:**
  Within Management WP 0.x, dedicated reference concept designs structured around the potential aircraft portfolio, ensures the transverse view between contributing technologies and focusing demonstrations path toward identified application targets. An essential role of the OAD & CM WPs responsibilities is to ensure full coherence between ITD Airframe and IADPs in the case of activities oriented to be finally tested in the IADP demonstrators. The role of these integrators is to manage (or be the focal point for) the overall demonstrator schedule, being the pulling agent of the technologies embedded in the Airframe ITD.

- **Avoidance of duplication (internal & external):**
  Thanks to both the interfacing management structure and the grouping of common technology developments in transverse WP

- **Control the management costs:**
ITD split into 2 homogeneous (technologies, applications, partners) lines of activity to reduce the scope of the operational day-to-day management to be assumed by each leader

### 9.5.2 Overall Aircraft Design & Configuration Management

It is important that the development of the technology base is correctly driven toward the need for a future insertion into a next generation of aircraft, in order to avoid focalisation on local optima & maturation of technologies whose benefits would be turned to zero once inserted in a concept, due to integration issues or mismatch between solutions.

To achieve this objective, a set of conceptual design activities around reference configurations of future generation of product will be carried out all along the CSII program, in order to:

- Analyse the different architecture trade-offs, and the best way to maximize the benefits from the emerging technologies.
- Generate high level requirements and relevant set of specifications to the different developments & demonstrations, and provide rationales & quantifications to orientate developments & demonstrations, and manage the iteration loop between the technology developments and the concept design.
- Assess the achievable progress toward the societal challenges for a smart, green and integrated transport by inserting the new demonstration technology into some new & consistent global concepts.
- Highlight the key feasibility issues and the major potential blocking points, in order to identify at the architecture level potential integration solutions, so as to validate the technology feasibility from the architectural point of view.
- Provide integrated inputs to the Technology Evaluator or the eco-design synthesis, directly or through IADPs.
- Ensure the interfacing between the different actions inside the ITD, with the different ITDs and IADPs and ECO transverse technologies so as to ensure the consistency of the different technology objectives from Airframe, Engine and Systems point of view, and to ensure the feedback loop between technology demonstration and technology insertion.
- Support by data & analysis the technical coordination of the Airframe ITD.

This works will be the backbone for the aggregation of ITD results to feed the Technology Evaluator analysis, and will act as the interface body with the Technology Evaluator management structure.

Conceptual design and modelling, including full aircraft aerodynamic analysis, general layout, structural architecture analysis, controllability analysis, system integration & performance analysis (including operational flexibility, maintainability, ecologic impact and passenger comfort) will form the core of activities, supported by experimental validations such as Wind Tunnel Testing.

The European Aircraft manufacturer community offers to the market a large & diverse range of products, from the rotorcraft to large passenger aircraft, also including Regional Aircraft, Business Jet and small transport airplane. It covers a very large domain of capabilities and technology requirements, and shares a large technology base. Nevertheless each segment has some own specificities, due to different customer requirements, addressing different mobility needs. Therefore, within the Management Activities of the ITD Airframe, 5 Interfaces & Cross-Interaction Work Packages will address each of the segments respectively.

For the aircraft segment supported by a dedicated IADP, concept explorations and trade-off analyses will be performed inside the IADP, and the work to be performed in the ITD Airframe Interfaces & Cross-Interaction Work Packages will mainly focuses on the good alignment of relevant ITDs demonstrations toward the IADP...
favoured concepts, and ensure a good and efficient interfacing between IADP and ITDs, while the Business Aviation and Small Air Transport for which no dedicated IADP exist, their interfacing works will include concept exploration and trade-off analysis. Interfacing and results integration with Eco-Design transverse activities will ensure consistent environmental and production efficiency.

- **Business Aviation Overall A/C Design and Configuration Management**

*Business aviation* accounts in number for about as many aircraft as commercial aviation. Its use will continue to grow steadily (with deliveries expected to double\(^\text{18}\) over the next 10 years). Business aviation mainly operates as a complement to commercial aviation. The expansion of business aviation is a key contributing tool to Europe’s economic growth, offering high-end mobility services for businesses harshly competing in the global playing field. It facilitates quick access for business to markets and regions not well served by commercial airlines, and supports the objective of seamless door-to-door mobility in Europe in less than 4 hours. It supports the global decongestion of air transport, by favouring the use of secondary airports. Therefore, the emergence of advanced new business jet concepts is subject to significant improvements in its way to address the mobility aspirations of Flightpath 2050 for versatile and time efficient travel whilst reducing its environmental footprint, and limiting noise pollution around populated areas of Europe. Business aviation shares most of its innovation objectives with the other air transport modes, in particular with regards to greenhouse gas emissions, noise or safety. But it also seeks specific step-change technologies, which are driven by its own bespoke needs:
- Very flexible operations;
- The requirement to use local airports in dense urban environments, as well as to access remote locations with reduced infrastructure;
- Seamless operations in a heavy traffic;
- Cost-efficiency at high speed for a wide array of missions (long haul and short stage lengths).

Implementing a sound multidisciplinary approach, advanced concepts of business jet will be derived based on the set of promising *Clean Sky* & *Clean Sky 2* technologies, to manage overall trade-offs at architecture level and assess feasibility and benefits of technology insertion into viable possible future concepts. These studies will drive the interactions with the other IADPs and ITDs from the future business jet aircraft perspective, and ensure a focused interaction with the transversal actions, namely the Technology Evaluator and Eco-Design. In addition to the global configuration analysis and concept design of Airframe innovative technologies insertion, the architectural trade-offs analysis will be enlarged toward the consistent integration of Airframe and System innovations, to take into account emerging trends like, for example the emergence of More Electrical Technologies or Smart Secondary Power Management.

- **Small Air Transport Overall A/C Design and Configuration Management**

Small Aircraft Transport (SAT) refers to the small aircraft used for passenger transport (up to 19 passengers) and for cargo transport, belonging to EASA’s CS-23 regulatory base (whereas the other aircraft categories relevant to *Clean Sky 2* all belongs to the EASA’s CS-25 regulatory base).

SAT, especially the area of versatile utility aircraft for cargo and passenger transport, is dominated by a lack of suitable, modern and cost efficient air vehicle. The ACARE’s goal of increased mobility requirements with seamless travel and an envisaged door to door travel of 4 hr time requires significant improved or even new approaches to design and especially for manufacturing of aircraft in this extreme cost sensitive market segment with its low volume sales of aircraft. SAT air vehicles supports travel in and out of remote areas with low infrastructure (i.e. unpaved runways and water operations) and feeds the hub concepts of the large aircraft

\(^{18}\) Honeywell Aerospace estimates, NBAA convention, November 2011.
transport systems with air vehicles with up to 19 passenger and with a large aircraft compatible cargo concept with suitable and easy to transfer units (i.e. LD3 containers). Based on the boundary conditions, SAT airframe will focus on the utilization of cost effective materials and improved production technologies for fuselage and wing. To support transversal activities within (SAT) airframe ITD in particular and over all 3 ITDs with its SAT topics in general, one of the SAT overall A/C design tasks will be to establish a “reference aircraft” to define and to establish reference data for a conventional state-of-the art 19-seater turbo-propelled aircraft against which the improvements of SAT Clean Sky 2 results can be measured and validated.

Research and definition of a cost effective and competitive future small aircraft will be part of work and new concept as DMU demonstrated, as a supporting case for the co-ordination of transversal activities over the ITD tasks with SAT involvement.

This activity will concentrate on:
- The coordination of research and application of technologies in all areas of aircraft design;
- The definition of a state-of-the art “Reference Aircraft”;
- The research and definition of a cost effective and competitive future small aircraft;
- The coordination of transversal activities over the ITD tasks with SAT involvement (call coordination, technology evaluator). A dedicated attention will be paid on the good coordination and technology flow from ITD systems for the demonstrations in Airframe of advanced integration of systems in small aircraft.

In addition, the activity will be based on a multi-disciplinary aircraft design concept, supported by 2 key demonstration activities:
- DMU for a future small green aircraft in 19 seats commuter category
- Concept and costs analysis of future small green aircraft

- **Large Passenger Aircraft Overall A/C Design and Configuration Management**

Air transport by large passenger aircraft does represent by transported passengers, goods by numbers and distance, as well as with respect to the volume of the market, turnover and the number of employees engaged in manufacturing, MRO and operations the largest sector in civil aviation. With Airbus holding close to 50% of the market share of civil transport aircraft above 130 seats, R&T towards ACARE and Horizon 2020 targets is of critical importance to contribute to worldwide environmental targets and to maintain and strengthen the leadership of the European aviation industry in the next decades. Both targets require a leadership role in innovation, and to secure the capacity and the capabilities to integrate the most potential new technologies into the next generation of large transport aircraft, with the effective support of the relevant supply chain. Clean Sky 2 will engage a consistent set of related research and development activities with scaled demonstrations at component level and high level integrations at full aircraft level articulated around the LPA IADP and the 3 ITDs. Therefore, a close cooperation and an efficient interfacing of the Airframe-ITD and the complementary large demonstrator activities in the Large Passenger Aircraft IADP is necessary and is the subject of the relevant Interface & Cross Management activities. It will ensure a proper flow down of the LPA demonstrator requirements and interface specifications from the LPA IADP, and that relevant developments throughout the Technology Stream, and technological enablers maturation will be done adequately to LPA aspirations, as well in term of schedule than in term of minimal performances and applicability.

- **Rotorcraft Overall A/C Design and Configuration Management**

Future generation of rotorcraft will dramatically increase their performances and environmental compliance. The synthesis activities in the Airframe ITD are critical to ensure an excellent interfacing with the major rotorcraft
IADP demonstration, so as to get a smooth convergence of the different ITDs & Technology Streams developments toward the global demonstration driven by the IADP. Therefore, they will be decomposed around the two major orientations contemplated for future rotorcraft concepts in the rotorcraft IADP: the compound rotorcraft subject of the LifeRCraft demonstration, and the tilt rotorcraft, subject of the NextGenCTR demonstration. It will enable:

- To flow down the rotorcraft demonstrators requirements and interface specifications from the IADP R/C LifeRCraft & NextGenCTR Demo Projects in the scope of Airframe components and coordinate the design and manufacturing of specific airframe parts (wing and fuselage assembly) and ensure consistency of verification and validation activities for delivery of project compliant demonstrations & demonstrator components for aircraft level integration, testing and flight demonstration in the Rotorcraft IADP Demo Projects.
- To perform the planning, coordination, risk management, reporting & dissemination activities concerning the Rotorcraft related contributions to Airframe ITD.

- **Regional Aircraft Overall A/C Design and Configuration Management**

The successful development and maturation of technologies for regional aircraft as well as the successful ground demonstration program (Wing, Cockpit, Nacelle) in the Airframe ITD, in conjunction with the in-flight demonstration and full scale ground demonstrations in the R-IADP, will represent a step change in regional aircraft that at the time of program starting is based on almost conventional configuration and mature technologies, most of them developed back in the 80’s.

The technologies for regional aircraft to be developed within the Airframe ITD are essential for the achievements expected by major demonstrators of the R-IADP (“Hi-lift Wing / Cockpit” FTB2; “Fuselage + Pax Cabin Integrated Demo”). The global convergence in objectives & technology between Airframe ITD activities and the R-IADP demonstrations impose a close, well managed interfacing between these two main demonstration paths.

These management activities will ensure:

- Correct interfaces and interactions with the R-IADP WP1 where:
  - Challenging high-level requirements will be established for the future High-Efficient Next Generation Regional Aircraft and innovative advanced bleedless Engine Requirements, such as a new Turboprop Engine rear fuselage installation (tractor or pusher configuration);
  - The preliminary sizing and configuration definition of innovative High-Efficient Next Generation Regional Aircraft configuration will be defined, entering into service on 2025, taking into account the Technologies Developments arranged along with 8 Technology Waves.

- Coordination management with the R-IADP for the definition and monitoring of the Technologies Waves Roadmaps containing technologies for regional aircraft to be developed and matured in the Airframe ITD;

- Coordination management with the R-IADP Demonstrators so as to ensure that the technologies developed in the Airframe ITD are delivered in accordance with the agreed schedule at the expected TRL level.

- **Eco-Design Management and MPR (Manufacturing, Processes and Resources) Technologies**

WP A-04 and B-0.5 are dedicated to the management and follow on of the Eco-Design activities performed for both HPE and HVCE activity line. See section 13 of the present document.
9.6 Activity Line A: High Performance & Energy Efficiency

9.6.1 Technology Stream A-1: Innovative Aircraft Architecture

I. Context & High-Level Objectives

The tremendous aircraft performance increase achieved during the last decades has been made mainly thanks to successive introduction of component improvements of a conventional overall architecture which has itself barely evolved since. The ambitious FlightPath 2050 targets cannot be reached only through component optimisation. It requires changes in the aircraft architecture itself, in order to overcome current limitations like achieving very high aspect ratio, to integrate radically new equipment like Open Rotor engines, to find new optima with a smart combination like between airframe & propulsion with the buried engine and also to maximise the individual gains on components thanks to better integration.

The aim of this Technology Stream is to demonstrate the viability of some most promising advanced aircraft concepts (identifying the key potential showstoppers & exploring relevant solutions, elaborating candidate concepts) and assessing their potentialities.

Four main work-packages will enable to explore:

- 2 major sets of innovative aircraft architecture:
  - **Advanced Engine Integration**, with WP A-1.1 Optimal engine integration on rear fuselage to propose new airframe concept around a conventional engine nacelle setting, serving both engine & airframe efficiency
  - **Novel Overall Architectures**, where step changes of the concept of one major component like the wing or the engine induce a comprehensive revisit of the aircraft architecture and of the engine integration. It is composed of 2 Work-Packages: WP A-1.2 Open Rotor (CROR) configurations and WP A-1.3 Novel high speed configurations (integration of a novel engine or nacelle concept).

- Complementary considerations transversal to all these new architectures, and that will help accelerate the transfer to and the acceptance by the market of such radical architecture transformations, through the implementation of Work-Packages WP A-1.4: Novel Certification Processes.

II. Scope & Added Value versus State-of-the-Art

![Figure 9.5 – Advanced engine integration and innovative aircraft configuration may serve high performances and sustainability together](image_url)
a. **Optimal engine integration on rear fuselage – A-WP1.1**

The global objective is to look at significant gain to the aircraft performances (fuel consumption, flight domain, agility, noise footprint, etc.) thanks to advanced engine integration at the rear fuselage.

Directions of exploration are as follows:

- **Significant noise reduction by using the airframe to contain noise.** *Clean Sky* works demonstrate the value of shielding for noise reduction and their overall feasibility. They also show the cost of penalties like aerodynamic efficiency decrease at high speed, low speed qualities, or structural weight increase. These barriers need to be overcome to actually put these innovative configurations on the market. Based on *Clean Sky* experience and learning, derivatives and new options have to be studied to achieve more mature, market viable configurations.

- **Smart, multidisciplinary management of the distortion for global optimization of the propulsion efficiency.** Currently, the engine integration is design so as to comply with the distortion criteria set forth by the engine, dictating severe constraints to the airframe. An innovating multidisciplinary approach would improve the global performances by introducing a trade-off between the constraints to globally optimise the aerodynamic & structural engine integration together with the engine efficiency.

Innovation targeted through the WP is new rear fuselage for an integration of the engine not only for the propulsion and flight control functions but also for noise reduction and efficiency improvement functions. As examples this includes concept such as:

- U type tail with engine located above horizontal plans for noise masking purpose.
- Boundary Layer Ingestion concept

b. **Open Rotor (CROR) configurations – A-WP1.2**

The radical change of the propulsion concept is targeting a 15-20% fuel burn reduction versus the performance of year 2014 state of the art propulsion system.

The integration of the advanced CROR propulsion system does require a substantial rethinking of the entire aircraft configuration.

Despite there is good evidence that the fuel saving potential of the CROR system is in fact unique compared to the best advanced and geared turbofan engine, and despite great steps have been made to solve the noise, certification, and many of the installation issues, the best candidate of engine-aircraft configuration is not yet identified further R&T work has to be done. Efficient integration design, certifiable installation & achievement of expected improvements in noise emission are critical to ensure the CROR concept is a fully viable competitor to the most advanced turbofan engines. For aerodynamically critical phenomena like blade/pylon interaction flows innovative technologies like pylon flow control might have to be studied in order to support efficient engine integration (from aerodynamic and aeroacoustic point of view).

From numerical and analytical studies and a significant number of wind tunnel tests with a small, but still significant number of down selected configurations done in *Clean Sky* SFWA it becomes evident, that further careful trade studies have to be made to identify the best candidate solution. The data on noise and aero
performance are critically needed to develop, improve and calibrate numerical tools for the design of a next generation CROR powered aircraft.

This action is dealing with high TRL technology R&T that is closely linked to the LPA-IADP WP1.1 flight test demonstration. The results will be used as input to mature the entire concept, but also to provide data for the detailed design of the propulsion system and the pylon for the flight test as well as initial substantiation data, etc.

![Figure 9.6 – Airbus concept aircraft with a noise shielded integration of an advanced CROR engine](image)

**c. Novel high speed configurations – WP A-1.3**

The global objective is to look at significant gain to the aircraft performances (fuel consumption, flight domain, agility, noise footprint, etc.) by introducing radically new concepts in the overall architecture:

- **Buried engine**
  The key expected benefits are:
  - Improve the propulsion efficiency by using the airframe to serve the engine needs, with Boundary Layer Ingestion;
  - Reduce drag & weight with the reduction of the global (airframe + nacelle) envelope by integrating the engine within the airframe;
  - Reduce wake’s drag and noise with innovative configurations like plane exhaust.

- **Wing combining high aspect ratio (drag reduction) and sweep angle (high speed performances)**: Disruptive configurations such as rhomboidal wing are necessary to combine those 2 requirements from the structural point of view. Other example is the use of canard for aerodynamic performance improvement.

![Figure 9.7 – Falcon concept aircraft with a rhomboidal wing](image)

**d. Novel certification processes – WP A-1.4**
Certification is an indisputable & essential pillar to the Air Transport Safety. But it is a long and resource consuming process, poorly adapted to the quick adoption of new technologies. The objectives of a novel certification process are:

- To insert “fair and reasonable” certification requirements in the early conceptual phase of disruptive configurations, to which the current applicable certification base might be inadequate;
- To help innovations to “get on-board”: reduce time & resources to validate safety of new systems, equipments, etc.;
- To introduce new, more efficient means of compliance;
- To reduce certification cost and efforts without any compromise on safety.

Such objectives require improvements in modelling accuracy & validity, better/finer understanding of some physical phenomena as encounter in real operating conditions (like ice accretion), new virtual tools, and the review of processes. The novel certification process should be supported by a comprehensive, adapted Information System. Progress in Product Life-cycle Management tools and integrated system behavior modeling could make more efficient the definition tuning and substantiation with respect to the certification requirements. In addition, the global PLM could improve the comprehensiveness of traceability of a/c definition all along with its life cycle. Demonstrations will focus on key certifications topics where a virtual or partly virtual certification could bring step changes in the global process like lightning impact on fastener & discontinuities, aerodynamics flow with ice accretion, de/anti-icing efficiency, external noise, flight handling qualities in flight domain limits, flutter substantiation, etc.

Complementary considerations will be also given to the qualification processes along with the certification evolutions, to guaranty reliability performance achievements at the global product level (from design to supply chain qualification). An initial application case is the reliability prediction methods to power electronic units.
### III. Technology Enablers and Demonstration means

#### Advanced engine integration

<table>
<thead>
<tr>
<th>WP A-1.1 Optimal Engine Integration on Rear Fuselage</th>
<th>Conceptual design, overall aircraft design, engine design, architectures, aero-shape optimization, vortex management (possibly done by active means like flow control) on afterbody for drag reduction, efficient air inlet, aero-structural validation, mechanical integration, structural optimization, active noise reduction, performance assessment, accurate noise footprint prediction</th>
<th>Ground test of engine with simulated distortions Large Wind Tunnel Test</th>
</tr>
</thead>
</table>

#### Novel overall architectures

| WP A-1.2 Open Rotor Configuration | Advanced pylon architecture, Active noise control with pylon trailing edge flow control, Validation of improved propeller design – acoustic & performance, Final down selection of best candidate engine integration – aircraft configuration | Large scaled wind tunnel test with CROR engine mounted to NSR (Next generation Short Range) aircraft. Details will be defined as result of the SFWA CROR review action in summer 2013. The target of the tests is to deliver a critical contribution to the definition of the configuration, integration of the pylon to the fuselage, and the engine setup and size, propeller design and size. |

| WP A-1.3 Novel High Speed Configurations | Conceptual design, overall aircraft design, engine burst considerations, engine design, architectures, aero-shape optimization, flow management techniques to reduce flow inhomogeneities at the intake, flight handling qualities, flexible structures, structural validation, performance assessment | WTT of innovative configurations Engine rig tests Possibly (according to preliminary studies results) flight test of aircraft with modified inlet to simulate the buried engine |

#### Eco-friendly and more efficient processes & technologies

| WP A-1.4 Novel Certification Process | Certification by models, lean and/or virtual means of conformity, innovative methods and data bases for certification, certification by increment; Advanced modelling, Accurate flutter prediction at high speed. | Wide range of local demonstrations to validate model accuracy & process validity, from ground (Wind Tunnel tests, structural tests, ...) up to flight activities (constitution of meteorological database, ...) |
## IV. Links & Interfaces

<table>
<thead>
<tr>
<th>Clean Sky Background</th>
<th>Inner ITD linkage (input/outputs)</th>
<th>Inputs from</th>
<th>Outputs to</th>
</tr>
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<tbody>
<tr>
<td>Aircraft concepts (business jet, Open rotor configurations)</td>
<td>With all the technology developments for the next generation wing &amp; fuselage, With the synergistic technologies on more efficient wing &amp; extended laminarity With the control technologies, flow and load controls Requirements refinements, technology maturation learning/results, interfacing/integration constraints, ... Exchanges with all the wing and fuselage structural developments &amp; manufacturing processes</td>
<td>Configuration and requirements from IADPs and overall aircraft design &amp; configuration management. Technology maturation learning/results, interfacing/integration constraints from engine &amp; system ITD. CROR engine installation &amp; integration elements</td>
<td>Requirements (performances &amp; interfaces) to engine &amp; system ITDs, inclusive of integration requirements to electrical systems Orientations, performance assessment &amp; synthesis to IADP, Global aerodynamic performance from simulation and wind tunnel tests and flightworthy test articles and substantiation for integration in IADP</td>
</tr>
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V. **High-level Plan**

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<tbody>
<tr>
<td>A-HPE</td>
<td>Innovative Aircraft Architecture</td>
<td><img src="image" alt="Diagram" /></td>
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**General notes:**
1) TRL are expressed with respect to the integration at the AIRFRAME level.
2) TRL are given with respect to the main demonstration stream. Within an activity line, you can have inserted some complementary/additional technology developments that will not achieve the same TRL target.

VI. **Partnerships**

Aircraft manufacturer (OEM) will perform the architectural works, concept definition & synthesis, based on their experience & knowledge on overall design.

Engine manufacturer (OEM) will contribute as core partners to the relevant integration studies, engine concepts analysis and engine performance assessment.

Research Institutes with excellent track record in physical simulations & advanced testing will contribute with focused advanced modelling & computational analysis, and use of their large test infrastructures (WTT) and reference data base and models. Contributions from partners with capacities to design, manufacture and test aircraft wind tunnel models are also expected.

The exploration of the most disruptive, far-fetched configurations could be explored by Research Institutes.

In addition to the expertise in modelling, certification processes enhancement may benefit from experience in data management and PLM solutions from IT providers.
9.6.2 Technology Stream A-2: Advanced Laminarity

I. Context & High-Level Objectives

This Technology Stream aims to increase the Nacelle and Wing Efficiencies by the mean of Extended Laminarity technologies.

Laminarity is one of the most important technological routes toward the high efficient wing, as it can provide a significant improvement on drag & aircraft aerodynamic efficiency.

Major demonstrations of natural laminarity for a partially modified wing will be performed in Clean Sky. This demonstration will validate the concept, but is still partial as laminarity will be achieved on a limited zone of the wing (roughly ¼).

The next step is now to achieve a full integration and a global demonstration of the complete wing. A full scale Natural Laminar Flow (NLF) Smart Integrated Wing demonstrator is the core of this Technology Stream, to ensure verification & validation of the laminar wing design, as a basic contributor to the global flying demonstration in the Large Passenger Aircraft IADP. In a complementary fashion, a particular analysis will be brought on the integration of laminar technologies applied to a wing with Turbo-propellers, inducing a particular turbulent environment.

Engine integration is also a key contributor to the overall aircraft aero-performance. Laminarity is also contemplated as a valuable path for improvement of the nacelle performances for new generation.

In the view of a larger implementation of the laminarity on other components than the wing & nacelle (tail planes, fuselage, and nacelle) and its extension toward higher speeds, technological works on Extended Laminarity will demonstrate potential and feasibility of key techniques & local systems, as a synergetic, transverse activity.

II. Scope & Added Value versus State-of-the-Art

a. Laminar Nacelles WP A-2.1

More Efficient Nacelles: with most advanced, most fuel efficient next generation turbofan engines growing even bigger in diameter, weight and friction drag penalties are the key parameters to determine the equilibrium between net benefit or net penalty when integrated and operated at aircraft level. Improvements in the nacelle global aerodynamic qualities are then required, and laminarity is a technology route with a good potential of achievement.

Up to now, laminar nacelle design is used only for large three shaft turbofan engines for long haul aircraft. Y2014 state of the art engine integration concepts for short and medium range aircraft or long range business jet do not feature any laminar technology.

With the significant progress made in laminar technology in Clean Sky SFWA and in running national funded R&T programs, the transfer and application to the nacelle design and structure concept is of high relevance to secure the fuel saving potential of the engine technology. Target benefit is to achieve a gain of ~3% drag at aircraft level compared to a nacelle of same size without laminar technology at same weight and effort in production and operation, and also to address this significant potential for even larger size engines expected for the next generation aircraft.
The key technical objective is of fully multidisciplinary nature: combine a low weight structure that enable high surface quality and low tolerances in waviness, steps and gaps, while ensuring appropriate integration and access to all relevant aircraft and engine systems. R&T of the manufacturing and assembling strategy and methods is a key element of the work package.

The innovation results in the challenge to design a nacelle to increase the laminarity up to 30% by taking into account many constraints and functions and for smaller aircraft:

- Accessibility to equipments for maintenance (rethink integration of the engine and related equipments),
- Integrated noise protection,
- Engine burst protection,
- Operational potential surface degradation.

b. **NFL (Natural Laminar Flow) smart integrated wing – WP A-2.2**

The current view is that the NLF wing has the firm potential to reduce the drag during cruise by 6-7% at aircraft level compared to the latest state-of-the-art turbulent wing. Giving the facts of more stringent surface quality requirements and a number of other constraints compared to the conventional design, the significant fuel burn potential of the NLF concept can only be turned into a strong contribution to industrial leadership if the drag benefit can be accomplished at similar or lower weight and comparable or lower efforts in production and MRO.

The key target is to develop and demonstrate an integrated wing concept that demonstrates this capability of the concept or even beyond.

Very recent results from major demonstrator programs, like Clean Sky SFWA indicate that all principle development challenges with respect to the aerodynamic and structural design, system development and integration and MRO (Maintenance, Repair and Overhaul) can be solved. However, a final major step of R&T and validation must be done on a fully integrated NLF wing concept to ensure that all challenges and industrialization are covered, namely performance driven design, manufacturing, system integration, assembly, maintenance and repair of such a concept.

The relevance of the demonstration is to accomplish a TRL6 of the concept with respect to the aspect of the European aircraft industry’s technology readiness in combination with the encompassed environmental target.
Even though there is a very sound basis of understanding of boundary layer flows, laminar to turbulent flow transition mechanism, and the sensibility of design characteristics to sustain laminarity this haven’t been seen in an industrial application. There are promising technologies that needs to be developed further to ensure that they meet requirements for industrialization in next generation of large commercial transport aircraft.

The “Large scale NLF smart wing integrated demonstrator” will demonstrate the synthesis of the results from SFWA and other programmes so that such a concept can be manufactured, produced and maintained in an industrial environment, which is the explicit objective of this demonstrator.

c. **Extended Laminarity – WP A-2.3**

**Advanced Laminarity Technologies**: the achievable level of laminarity (proportion of laminar surface, extension toward higher Mach number & Reynolds number, robustness to perturbations and so on) could be put forward, in particular thanks to the hybrid laminarity, with the introduction of innovative active systems, sucking or blowing the air flow.

The objective is to identify the concepts and to prepare the technology base that will be used in the different demonstrators embedding a laminarity objective. The state of the art is depending on the aircraft type, and is implemented in local, “narrow boundaries” solutions. Indeed, the biggest challenge to overcome lies in the combination of severe constrains from the aerodynamics configuration in terms of maximum lift, buffet limits, or leading edge sweep, etc. To fully explore the benefits from laminar technology, additional enabling technologies like active flow control at shock region or wing trailing edge could be essential to ensure laminar wing suitable sweep angles and/or extended Mach number ranges. Synergies are expected from common system architectures (for HLFC and active flow control). Extended aerodynamic performances & robustness are key points of optimal solutions, together with matching the requirements for manufacturing.

Based on the initial technology developments in progress with *Clean Sky SFWA*, and that are about to be engaged in AFLONEXT (Level 2 FP7 project), it will explore the hybrid laminarity techniques, define, develop and test using active blowing or sucking devices, and define concepts of integration (physical, thermal, energetic, etc.), including life cycle considerations (long duration –performance degradation, maintainability, etc).

Demonstration of integrated solutions will be performed in dedicated large demonstrations in the ITDs and IADPs, this developments being focused on definition of surface concepts embedding flow control system, and performing the necessary local demonstration to validate the flow control concepts and active devices.
### III. Technology Enablers and Demonstration Means

<table>
<thead>
<tr>
<th>Key Enabling Technologies</th>
<th>Key Demonstration Vehicle</th>
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<tr>
<td><strong>More Efficient Nacelles</strong></td>
<td><strong>More Efficient Nacelles</strong></td>
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<tr>
<td>WP A-2.1 Laminar Nacelle</td>
<td>WP A-2.1 Laminar Nacelle</td>
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<tr>
<td>• Aeroshape optimization</td>
<td>• Dedicated structural component tests</td>
</tr>
<tr>
<td>• Nacelle design with smart management of access doors and bleed apertures</td>
<td>• Full size nacelle structural demonstrator, manufacturing and assembly</td>
</tr>
<tr>
<td>• Manufacturing and assembly technology “low geometrical tolerance, high surface quality” based on CFRP composites with joints to hybrid components</td>
<td>• Demonstration of repair and cleaning technology</td>
</tr>
<tr>
<td>• Surface treatment and coatings with high erosion and self cleaning capability</td>
<td>• Demonstration of integration compliance with major system components</td>
</tr>
<tr>
<td>• Repair technologies for in-field “quick fix” for small damages and in-hangar for sever damages</td>
<td>• Flight test of a modified nacelle</td>
</tr>
<tr>
<td>• Large size demonstrator articles with high relevance for potential industrial application</td>
<td>Based on results, large scale flight test validation of some key demonstration article in LPA-IADP could be performed</td>
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<tr>
<td>• Flow control for engine pylons</td>
<td></td>
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<tr>
<td><strong>Efficient Wing</strong></td>
<td><strong>Efficient Wing</strong></td>
</tr>
<tr>
<td>WP A-2.2 NLF Smart Integrated Wing</td>
<td>WP A-2.2 NLF Smart Integrated Wing</td>
</tr>
<tr>
<td>• Light weight technologies</td>
<td>Key objective of the activity is to design, manufacture and test representative full scale test sections of a next generation natural laminar flow wing for a short and medium range large transport aircraft including all main features of structure and system. The structural design, manufacturing and assembly methods and the use of material shall be representative with respect to industrial aspects of high reproducibility, high production rate as well as MRO aspects.</td>
</tr>
<tr>
<td>• Use of the latest developments in materials technologies at a relevant TRL level</td>
<td>Next generation wing concept shall be validated with respect to the efforts in materials, tooling, manufacturing, integration and assembly of components and systems. Means of demonstration can be analysis, simulations and testing of the functionality of various parts.</td>
</tr>
<tr>
<td>• Multifunctional materials</td>
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<tr>
<td>• Manufacturing and assembly technologies, e.g. “close geometrical tolerance, high surface quality” based on CFRP composites</td>
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<tr>
<td>• Physical features of the design, integration of innovative wing system such as WIPS and control surfaces etc.</td>
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<tr>
<td>• Repair technologies for simplified over-night repairs in-field for small damages and enhanced repair technology for more complex damages.</td>
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<tr>
<td>Large size demonstrator with high relevance for potential industrial application</td>
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<tr>
<td><strong>Advanced Laminarity Technologies</strong></td>
<td><strong>Advanced Laminarity Technologies</strong></td>
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### IV. Links & Interfaces

<table>
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<th>Outputs to</th>
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<tbody>
<tr>
<td>Smart fixed wing basic laminar technology developed for the wing to be adapted to nacelle</td>
<td>With new materials &amp; advanced manufacturing</td>
<td>Configuration and requirements from overall aircraft design &amp; configuration management</td>
<td>Technology &amp; integration data to synthesis in overall aircraft design &amp; configuration management. Laminarity technologies demonstrator data to LPA IADP. Substantiation article ready for global validation to LPA IADP Interfacing requirement and structural architectural concepts to the high lift wing Further refinement of performance data to Technology Evaluator and Eco-Design to assess the potential of the technology on aircraft level, respectively for the entire component life cycle</td>
</tr>
</tbody>
</table>

Achievements of *Clean Sky* SFWA along with links that may be identified in some FP7 L1 - L2 research programs (AEROMUCO, EXTICE, etc.) Technologies recent and running national funded laminar wing programs
V. High-level Plan

VI. Partnerships

Aircraft OEM will perform the global trade-offs, set the requirements, manage the integration and, when appropriate, ensure the proper interfacing to the IADP. They will bring key contributions to the definition, development & testing of the demonstrators, based on their expertise in engine/airframe integration core issues pertaining to the nacelle design, and in structural design & aero-shaping design.

Core partners from engine & nacelle aero-structure industry will contribute for part design optimization & manufacturing.

The European aeronautics supply chain will also be involved for manufacturing and assembly techniques.

Research Institute & specialized research organisation will bring their expertise in modelling (CFDs, acoustics, power and so on) and advanced testing techniques and means.
9.6.3 Technology Stream A-3: High Speed Airframe

I. Context & High-Level Objectives

Speed & versatility are vital enablers of a flexible mobility. But they are difficult to reconcile from the overall design optimisation point of view (e.g. flexibility with low speed performances versus short travel at high speed), and speed usually came with an environmental cost (fuel consumption, noise...). The emergence of new generation of aircraft that will match the aspirations for sustainable high mobility requires step changes in the airframe concepts and technologies. Capitalizing on Clean Sky on-going achievements on wing efficiency and FP7 & national programs on composite structures, progress will be made on the wing, fuselage and cockpit in a consistent, integrated approach.

![Figure 9.9 – Novel wing structural design will highly use composite material](image)

This Technology Stream will address progress for each of the major airframe components throughout a set of 5 Work-Packages:

- **WP A-3.1 Multidisciplinary wing for high & low speed** will explore new structural wing design. The wing is a key contributor to the aircraft efficiency. Composite wings will be flying or be on final qualification stages on several commercial aircraft by 2014 (benefiting, in particular from national or previous FP programs). The aim is now to move one step further than those first generation of composite wing, with composite introduction strategy mainly driven by replacing one material (metallic alloys) by an lighter one (composite material). The challenge is to develop & demonstrate new wing concepts (including architecture) that do more than just using the weight reduction from the raw material. Changes in the wing conventional architecture are contemplated here for an extended flight domain (aerodynamics qualities & weight).

- **WP A-3.2 Tailored front fuselage**, **WP A-3.3 Innovative shapes & structure** and **WP A-3.4 Optimised cockpit structure** will deal with different progress pathes for an efficient fuselage. In the airframe, the fuselage structure has kept on with old conventional architecture since decades, the main improvement laying on design optimisation and significant progresses in the manufacturing process and substantiation process. The technical focus is here to consider fuselage (including cockpit) evolutions in shape or structure capable of withstanding enlarged flight domain and that will achieve significant performances gains like drag or weight reductions.

- Complementary considerations transversal to all the structure related advanced topics, and that will help accelerate the transfer to and the acceptance by the market of such radical high speed aircraft evolutions, through the implementation of **WP A-1.5 Eco-Design for Airframe**.

II. Scope and Added Value versus State-of-the-Art
a. Multidisciplinary wing for high & low speed - WP A-3.1

The objective here is to reconsider the wing architecture, with composite as an enabler of a structurally and aerodynamically more effective wing. As looking for a global optimum, the specification targets will integrate both high & low speed performances (using the demanding business aircraft case). Increasing the aspect ratio and decreasing wing thickness are rewarding strategies to reduce the drag, but are currently penalized by structural constraints (for instance, wing flexibility). Significant performance improvements in drag, robust in an extended Mach range, for a light weight, thick wing and with a higher effective aspect ratio could be achieve with optimized usage of composites and distributed controls.

The multidisciplinary approach will allow reaching new optimums by a smart optimisation jointly from the structure, aerodynamics and control points of views. Increase of performance (combination of weight and drag decrease and extension of the flight domain where very good aerodynamics qualities are achieved) shall come. To achieve such a high performance for all above mentioned optima, multifunctional concepts (e.g. active trailing edge flow control developed in AFLonext) could play an essential role. These might be required especially for thin flexible wings, for which spanwise circulation adjustments could further enhance the wing performance. With respect to the multidisciplinary approach, it is also necessary to validate that some local constraint or specific requirements does not risk counter-balancing the global overall optimisation. Therefore, specific local investigations, modelling improvements, sizing optimisations, design tunings and partial demonstrations on representative composite wing spar and skin panels will be done for high energy chocs on composite, to efficiently withstand strikes with birds or tire’s fragments on leading edges for these highly optimized wing concepts.

The objectives of those activities are not only to go beyond Clean Sky in term of the wing performance increase, but also to insert the economics & ecological aspects in the definition of new, multicriteria optimums, to achieve a high efficient wing together with affordable costs & environmental footprint decrease. The demonstration shall go all along up to the manufacturing & testing of complex integrated structure representative for a wing box, and also show compliance to manufacturing, cost & environmental constraints.

Innovations targeted are related to critical components tailored to the aircraft type:

- For the bizjet aircraft: design, develop, and ground test an innovative wing box. This includes increasing multidisciplinary design chain capabilities (shape optimization techniques for high & low speed),
- For the large passage aircraft: develop, manufacture and ground test an innovative next generation of light weight, low cost, highly integrated composite aileron.

b. Tailored front fuselage – A-WP3.2

The front fuselage is the part that enters into the airflow at and plays a very important aerodynamic role, but the degrees of freedom for its design are limited, with constraints like pilot visibility, sensor integration, ... A global rethinking of the fuselage could induce space for a true dramatic reshaping of the front fuselage, and offer new ways to perfect the aero-shape design, with innovative shapes and advanced system integration enabling:

- Laminar front part,
- Clean windshield integration,
- Protuberances and discontinuities suppression: antennas (radar integration), anemometry, landing gear, in/off-takes, etc.
This is a new concept whose feasibility has to be demonstrated, up to the manufacturability & assembly-ability with the required quality of surface. New concepts of part (windshield...) or equipments (anemometry...) integration have to be developed, including probable design evolutions of these parts and equipments. Final benefits have to be assessed in the context of a global aircraft concept.

c. **Innovative shapes & structures of fuselage – A-WP3.3**

The objective is to achieve breakthrough on efficiency (combined weight & drag reduction) of metallic fuselage with:

- Introduction of step changes from the materials, like with the “low density” aluminium alloys (Al-Mg) that are just now emerging from the supplier base. Compare to the “high resistance” alloys (Al-Li) family (which is just starting to be introduced on aircraft product), these new materials will induce a different weight saving strategy and will lead to novel architectural design that needs to be demonstrated & validated.
- Changes to the structural design, like with multifunctional material like structural windows allowing new load paths or structural absorbing materials enabling the suppression of some material layers
- Structural optimization for parts with complex shapes highly constraints by aerodynamic optimization, such as rear fuselage, with assembly of thin composite panels on metallic structure.
- Concept optimization with multidisciplinary design (e.g. shaping or aerodynamics devices could suppress aerodynamic noise source, reducing weight of necessary absorbent layers), and reduced constraints from life cycle (erosion resistance, failure tolerance, fatigue control). A global noise control strategy at the overall fuselage design will be analysed, to optimize the full chain of noise treatment, from reduction of the noise sources, management of the noise transmission (i.e. active noise control at engine/fuselage interface) and noise absorption.
- Optimization of the internal volume and lay-out while reducing the wet surface thanks to non circular shapes. The global benefice of such shape evolutions still needs to be carefully assessed, as a trade-off between the aerodynamics gains and structural & integrations penalties.

The success of the introduction of these new technology is also determined by the ability to concurrently bring further progress on the eco-design issues (potential societal & regulatory blocking points) & cost production efficiency (potential market blocking point). Therefore, the progress in performance needs to be assessed against the environmental impact & resources consumptions of the production methods & processes. The assessment will be done thanks to a representative demonstration of cost effective production of complex metallic shaped parts (such as the rear fuselage): easy assembly, automation, high speed machining, waste reduction, in close relationship with WP A-1.5 related to Eco-Design for Airframe.

e. **Eco-Design for Airframe – WP A-3.4**

Eco-Design for Airframe is to explore ways matching the future market pressures that are likely to include the combination of price pressure from new competitor and high level of expectations from the eco-compliance. Such should apply to all airframe components: the composite wing, the metallic or composite fuselage and the cockpit structure. The global technical objective is to make available to the aerospace industry and its supply chain a set of new technologies reducing the environmental footprint of the aircraft production from the global life cycle point of view: develop new processes, methods & manufacturing & recycling technologies that enable Green Manufacturing, Green Maintenance and Green disposal, End Of Life, at affordable conditions by implementing an European logistic network for EoL aviation materials.
Beyond the REACH compliance (suppression of use of environmental harmful chemical for the aircraft production), keeping in Europe, in the long term, the aircraft & systems production by manufacturer & their supply chain needs further developments of not only environmental respectful but also cost-efficient processes for the production, maintenance & disposal of the aircraft. Such includes also the reduction of resource consumption (from raw material to water& energy). Within Clean Sky basic green manufacturing technologies were elaborated and demonstrated at component level; also methodologies for Life Cycle Assessment were implemented. It is now important to integrate these technologies in the design and manufacturing of next generation elements, and to drive the individual processes development toward a global positive environmental impact (e.g. a green coating techniques whose benefit would be annihilated by disposal issues) throughout an integrated Life Cycle Assessment (LCA) approach. The metallic & composite fuselage demonstrators will be the reference cases both for the demonstration of the green D&M and for the LCA.
### III. Technology Enablers and Demonstrations means

<table>
<thead>
<tr>
<th>New structural wing design</th>
<th>Key Enabling Technologies</th>
<th>Key Demonstration Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WP A-3.1 Multidisciplinary Wing For High &amp; Low Speed</strong></td>
<td>New architectural design, new shapes taking benefits from composite’s high flexibility and ability for shape forming, improved sizing criteria, steering (i.e. shape/structure coupled optimization), distributed control, new material, high rigidity fiber, sizing &amp; structural optimization for high energy chocs, low cost manufacturing, &amp; assembly techniques, eco-friendly manufacturing (global footprint), monitoring, quality inspection techniques (NDT, ...), new coatings (erosion-proof, anti-accretion of ice &amp; bugs ...).</td>
<td>Partial/local wing box demonstrator: from design up to manufacturing &amp; assembly, to achieve the feasibility of intensive optimization of composite application and validation of structural concepts for key wing components. Ground structural tests (static &amp; dynamics).</td>
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<tr>
<th>Efficient fuselage</th>
<th>Key Enabling Technologies</th>
<th>Key Demonstration Vehicle</th>
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<tbody>
<tr>
<td><strong>WP A-3.2 Tailored Front Fuselage</strong></td>
<td>Overall innovative front fuselage concept design in consistency with the Overall Aircraft Design, aerodynamic shaping, natural &amp; hybrid laminarity, advanced manufacturing &amp; assembly techniques, surface integrity, seamless part junction/integration, joins and discontinuities, innovative antenna integration, novel anemometry, Synthetic Vision Systems based cockpit, thermal cooling</td>
<td>Large Wind Tunnel Partial Structure ground demonstration of the surface integrity &amp; assembly quality for representative shapes and junctions (windshield integration) Simulation for cockpit with reduced lookdown visibility Aero demonstration of realistic structure (large Wind Tunnel Testing and/or Flight Testing of a new shape fitted on an existing aircraft, to be determined according to preliminary results)</td>
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</table>
### WP A-3.3 Innovative Shapes & Structures Of Cockpit & Fuselage

<table>
<thead>
<tr>
<th>Key Enabling Technologies</th>
<th>Key Demonstration Vehicle</th>
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<tbody>
<tr>
<td>New architectural design, new shapes to optimized drag, wing-body fairing optimization at high speed, structure &amp; volume, aerodynamic noise reduction, noise transfer reduction, active noise control, systems &amp; networks physical integration, improved sizing criteria and optimized fatigue sizing, failure tolerance, new low density material, multifunctional materials, composite structure optimization, low cost manufacturing &amp; assembly techniques, high speed, highly automated, low waste manufacturing, health monitoring, quality inspection techniques (NDT, ...), new coatings</td>
<td>Partial demonstrator for bounding, forming, processing, machining, assembly a fuselage part with new alloys, and ground testing</td>
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<td>Fuselage panel demonstrator of assembly for innovative shapes (e.g. link to innovative engine integration at the rear). Partial demonstrators could be used as eco-design case test to assess the global footprint of its production. Local demonstrator of multifunction materials, and their integration in a structural part.</td>
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</table>

#### Eco-friendly and more efficient processes & technologies

**WP A-1.5 Eco-Design for Airframe**

- Eco efficient technologies & logistics
  - for Carbon Fibre Reinforced Polymers structures: wing stiffened panel by infusion process, integral stiffened structures, low energy curing
  - for thermoplastics: thermoplastic composites for aircraft structures & interior applications
  - for special polymers applications: composites for high temperature applications, conductive composite
  - for metallic structures: light alloys stiffened panel, long life structures, light alloys and surface treatments, corrosion protection and/or self-healing, Magnesium Technologies
  - for biomaterials: green polyurethane foams for aircraft seating, secondary structures and interior furnishing
  - for electronics materials: electronic connectors, lead-free solder, and aircraft wiring
  - for tribology: novel coating & corrosion protection
  - for low energetic, waste saving novel processes: welding, forming, bounding, surfacing
- Processes will be demonstrated individually by representative local demonstrator
- The integration of the environmental gains into a global impact assessment of the life cycle will be done using the reference case of the metallic fuselage section and the composite fuselage demonstrator of the Airframe ITD.

### IV. Links & Interfaces
<table>
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<tr>
<th><strong>Clean Sky Background</strong></th>
<th><strong>Inner ITD linkage (input/outputs)</strong></th>
<th><strong>Inputs from</strong></th>
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<tbody>
<tr>
<td>Smart Fixed Wing</td>
<td>With Innovative aircraft architecture</td>
<td>Configuration and requirements from overall aircraft design &amp; configuration management</td>
<td>Technology &amp; integration data to synthesis in overall aircraft design &amp; configuration management. Footprint data to Eco-Design assessment Laminarity technologies &amp; wing Demonstrator component to LPA IADP Eco-Design transverse activity Further refinement of performance &amp; emission data to Technology Evaluator</td>
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<tr>
<td>AFLonext</td>
<td>With new materials &amp; advanced manufacturing Exchanges with the fuselage structural developments Exchanges in the synergetic efficient wing technologies transverse activities Exchanges in the component design &amp; validation cycle. Exchanges with all the wing and fuselage structural developments &amp; manufacturing processes</td>
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<td>Eco-design Life Cycle Assessment</td>
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<td>Clean Sky Eco Design</td>
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<td>Specifications &amp; interfaces from the LPA IADP</td>
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*Clean Sky 2 Joint Technology Initiative in Aeronautics*
### V. High-level Plan

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<tr>
<td>A-HPE</td>
<td>High-Speed Airframe</td>
<td>Structure (Wing, Fuselage)</td>
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<td>Eco-Design for Airframe (WP A-3.4)</td>
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<td>Clean Sky Complements</td>
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General notes:

1) TRL are expressed with respect to the integration at the AIRFRAME level
2) TRL are given with respect to the main demonstration stream. Within an activity line, you can have inserted some complementary/additional technology developments that will not achieve the same TRL target
VI. **Partnerships**

Aircraft OEM will perform the global trade-offs, set the requirements, manage the integration and, when appropriate, ensure the proper interfacing to the IADP. They will bring key contributions to the definition, development & testing of the demonstrators, based on their expertise in design and manufacturing expertise of advanced composite structures, metallic structures and wing & fuselage assemblies.

Core partners from aero-structure industry will contribute for part design & manufacturing of advanced composite & metallic parts, including assembly and junction techniques (joins ...), hybrid structures (mix of composite & metal in a structure), lightening protection, surface protection, new materials, material coupon testing, ground (static & dynamic, including wing static test) testing. Knowledge & capabilities are also required for automated manufacturing and advanced production processes & tools.

Equipments/Sub-systems providers will fit their innovative component in the structure when appropriate for integration demonstration purposes. Specific focus will apply on Synthetic Vision System for low visibility techniques, novel anemometry, and advanced sensor integration techniques (antennas, radar, communications...).

Research Institute will bring their expertise in modelling (CFDs, static & dynamic analysis, lightning, ice accretion, materials, assembly & join techniques, manufacturing process, fatigue ...) and advanced testing techniques and large test infrastructures (i.e. wind tunnel tests).

Integrated aero-structure manufacturer could also developed competitive approach for composite optimisation throughout dedicated demonstrator of complex aero-structure wing assembly, in order to explore other alternative options.

For Eco-Design, Core partners will bring contributions in advanced composite & metallic parts production, joins and seals, surface protection, new eco-friendly production recycling techniques, new processes, new materials (new aluminium alloys manufacturer, advanced composites ...) and ground testing.

Research Institutes, SMEs and other enterprises will provide a strong support with their excellent track record in simulation & modelling (manufacturing process, advanced coating...), material technologies, Life Cycle Assessment techniques and tools.
9.6.4 Technology Stream A-4: Novel Control

I. Context & High-Level Objectives

Flight control systems are now very efficient thanks to all the significant improvements that have been achieved in the last decades, participating to both flight safety and aircraft flight qualities. Full digital control system, efficient actuators are now mature flying technology. The new challenges that could bring step change gains do not more lay in the optimisation of the flight control system component performing its duty of controlling the flight, but to open the perspective to the flight control system as a system contributing to the global architecture optimization. It could contribute to sizing requirements alleviations, thanks to a smart control of the flight dynamics.

The key objective is to reduce the global aircraft weight, either by mutualisation of functions (lift & control) in a single mobile part, reducing then the number of control surfaces, or by load alleviation with active load control. Such will lead to the reduction of consumed fuel and CO₂ footprint.

II. Scope & Added Value versus State-of-the-Art

a. Smart mobile control surfaces – WP4.1

Multifunctional control surface combining the high lift & the flight control functions into one single mobile device allows introducing architecture simplification, with a reduced number of mobile surfaces and new redundancy strategy. Fewer parts, simplified architecture will mean lighter weight, better reliability & maintainability.

The smart flap in Clean Sky will validate the value of the mutualisation of mobile surfaces through the development & testing of one mechanical selected device and mechanical architecture, but it also pinpoints limitations & drawbacks which could refrain from their possible adoption in a future aircraft program. Further developments of alternate mechanical solutions identified based on Clean Sky demonstrations will lead to the global demonstration of a new, more effective mechanism.

Complementary solutions (pre-developed in Clean Sky) like control surfaces equipped with active flow control for various purposes should also be studied in order to increase the range of option for down selection. Such active systems could be used for several objectives (all studied in Clean Sky) like more lift for enhanced high lift performance or reduced lift for off design cases.

In addition, the new concepts will also have to be compatible with the future increase of integration of electrical components in the wing. Integration of electrical powered equipment on a mobile surface such as an Electrical Ice Protection carpet on leading edge slats may refrain from the emergence of the More Electrical Aircraft. Clean integration of equipments and advanced mechanisms for the electrical connection on mobile parts needs to be design, and demonstrated with respect to all the different constraints from operations (including certificability, robustness, duration, maintenance, reliability, etc.).

Major innovations considered through the WP are as follows:

- Integration of EWPIS in a slat, including smart management of the electrical connexion with moving part. Different innovative systems will be considered: pure electrical concept, hybrid electrical / pneumatic concept and electro-mechanical concept for longer term application. Related tasks are design and demonstration of the feasibility of EWPIS integration in a slat for a bizjet application. This includes design, manufacturing and
testing of a full scale portion of a slat. Evaluation of benefits (energy, weight...) will be carried out at aircraft level.

- New and innovative design solution to control the aircraft with the use of multifunctional materials. Sub and full scale control surfaces will be used for demonstrations.

b. **Active Load Control – WP4.2**

The general objective is the reduction of the structural weight by increasing the sizing margins considered today. His is obtained through the smart use of the flight control system, in order to:

- Alleviate gust load: the aircraft structure sustains a surge of load when facing a gust, making it a sizing case for the structure. An adapted control of the aircraft to smartly fly into a gust will counter-act the gust effects, leading to the load alleviation. Once mature (i.e. validated from functional & safety points if view), this technology will enable to decrease the maximal load specifications, leading to a significant weight reduction.

- Counter-act flutter initiation or vibrations: the smart motion of control surfaces can allow controlling vibration propagation in the wing & dumping the flutter initiation. When mature (i.e. demonstration of the simultaneous ability of the flight control system to dump & to control the flight) this technology will allow to reduce flutter constraints for the structural sizing, leading to a significant weight reduction.

Main activities are the development of specific control laws for load control and flutter margin increase. The demonstration is based on ground & flight tests on an existing modified aircraft associated with modelisation activities.
III. **Technology Enablers & Demonstration Means**

<table>
<thead>
<tr>
<th>Key Enabling Technologies</th>
<th>Key Demonstration Vehicle</th>
</tr>
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<tbody>
<tr>
<td><strong>Control</strong></td>
<td></td>
</tr>
<tr>
<td>WP A-4.1 Smart Mobile Control Surfaces</td>
<td>Smart mechanism, aero-elasticity, mechanical structure, assembly, actuation &amp; control. Control surfaces with flow control on demand capability.</td>
</tr>
<tr>
<td>WP A-4.2 Active Load Control</td>
<td>Control algorithm, aero-elasticity, structural dynamics, testing methods &amp; tools, sensing, actuation</td>
</tr>
</tbody>
</table>

IV. **Links & Interfaces**

<table>
<thead>
<tr>
<th>Clean Sky Background</th>
<th>Inner ITD linkage (input/outputs)</th>
<th>Inputs from</th>
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<tbody>
<tr>
<td>Smart fixed wing: smart flap demonstrator FP7 : AFLONext and active control related projects</td>
<td>With Innovative aircraft architecture Exchanges in the component design &amp; validation cycle. With the extended laminarity activities With the advanced nacelle development activities</td>
<td>Configuration and requirements from overall aircraft design &amp; configuration management System ITD for advanced equipment concepts: actuation, sensing, ice protection, etc.</td>
<td>Technology &amp; integration data to synthesis in overall aircraft design &amp; configuration management. Further refinement of performance data to Technology Evaluator and Eco-Design to assess the potential of the technology on aircraft level, respectively for the entire component life cycle</td>
</tr>
</tbody>
</table>
V. High-level Plan

VI. Partnerships

Aircraft OEM will perform the global trade-offs, set the requirements and manage the integration of the demonstrators. They will ensure definition, development & testing of the demonstrators thanks to their key expertise in the flight control and background on aircraft structural loads & dynamics management.

Core partners will contribute for design & manufacturing of mobile parts (flaps) & actuation systems. Expertise in sensors for the control loop is also expected.

Research Institute will bring their advanced knowledge & expertise for the dynamical computational analysis and advanced control methods (non linear), including advanced testing techniques and means.
9.6.5 Technology Stream A-5: Novel Travel Experience

I. Context & High-Level Objectives

The cabin interiors progress is indeed on the path of all societal challenges of the future transport system:

- As a key enabler of product differentiation (being the first contact between the aircraft & the passenger. Enhancing the cabin qualities is directly helping to maintain the European aeronautics industry in the leadership group;
- As having an immediate & direct physical impact on the traveller (being the interface between the aircraft & the passenger). Enhancing the cabin qualities can dramatically change the travelling experience by the passenger, both in term of individual efficiency (travel as productive time, leaving the aircraft in perfect shape, ready for a good full day, …), and well-being (comfort, health, …);
- As having a great potential in terms of weight saving & eco-compliance: the cabin internal equipments & systems account for a significantly more than the passenger weight it welcomes, and is the first entrance gate for bio-material and advanced eco-friendly furniture in the aircraft. Enhancing the cabin performances directly impact the aircraft performances.

No significant cabin related works have been performed in Clean Sky, or in the FP7. There is an urgent need to introduce step changing innovations in the cabin, for all its aspects: volumes arrangements, furniture, galleys & seats, equipments (from the coffee machine design to waste recycling), and technologies (efficient absorbing materials, bio-materials, crash resistance, chemical clean atmosphere …). Development activities are about optimizing the cabin (in its different meaning, from an efficient & warm hosting of the passenger to a cost-efficient completion) and enhancing the quality of service.

II. Scope & Added Value versus State-of-the-Art

The technical focus is here to explore routes for a more efficient cabin from aircraft performances & airline operations point of views (high flexibility, low weight, low cost) while achieving a high level of passenger’s environment quality and passenger comfort & well-being thanks to a human engineering approach. Such will be served by 2 work-packages.

a. Ergonomic Flexible Cabin WP A-5.1

The global objective is to offer a new value for air travel by providing the passenger the cabin environment expected for the time he is on board. Future aircraft shall enable the operator to offer the passenger as customer a much wider flexibility of a personal environment much more based on individual needs.

In a confinement of an aircraft with obvious constraints, but also margins, creating a novel travel experience for the passenger of the future is the key intention this work package. The ergonomic flexible cabin aims to provide entirely new options to use the time during the air travel. Passengers will have the flexibility to ask for much more than a seat in an aircraft.
2 key issues will be addressed:

- **User centered cabin**
  
  Scope aims at the development and testing of an innovative cabin architecture focusing on so called specific user groups. The projet has 3 key aspects:
  
  - Requirements for specific user groups. The project will collect requirements for specific user grounds like obsess PAX, families, generation 55+, Persons with Reduced Mobility (PRMs), PAX with different cultural background, but also for crew. For this purpose, requirement collection will be organized through different scenarios like crew fatigue investigation, mock-up tests or even flight tests to quantify the impact of Cabin Windows on Passengers.
  - Future Cabin Concepts. Several used cases will be defined for validation of the requirements. Main focus will be on a new seating concept called multifunctional seat bench and on a new 37” PRM Laborotary
  - Aircraft Application. Although targeted future Large Passenger Aircraft application, in consisency with the overall Clean Sky 2 approach, direct spin-offs of the developed Cabin Technologies and Concepts should flow in legacy aircraft like A320; A380 or A350.

- **Immersive Cabin Services.**

  Definition of Up-to-Date hardware for immersive applications (e.g. Smart Googles, Google Glasses, etc.)

-b. **Office Centred Cabin WP A-5.2**

Business aviation seeks to turn the travelling time into effective productive time, boosting the competitiveness of companies playing in the global field. With respect to an already sound state of the art where 60 % of business jet user assess the productivity in flight at as good or better in average than typical hours in office (2009, Harris Interactive Survey – The Real World of Business Aviation), several barriers still need to be overcome:

- The relatively limited cabin space reduces the flexibility of configuration and internal layouts;
- The weight penalty of the most confortable cabin interiors downgrades the environmental performance of the aircraft;
- The aircraft owner’s aspiration for a fully tailored cabin serving best its specific business & travelling needs is matched barely in a cost-effective way;
- Short cycles of consumer’s products developments are often not compatible with integration cycle of the aviation industry.

The technical focus is here to rethink the global cabin arrangement and equipment in order to create both a good, enjoyable operating environment, matching the aspirations of business travellers and smartly suited to each time sequences (service) in a long haul flight: working, meeting, eating, leisure, resting, sleeping, washing... inside a small volume typical to Business Jets cabins.

The objective is to introduce novel cabin internal layout and new equipments to enhance the passenger comfort, to foster the quality of service delivered in the cabin, creating then an ambiance and environment quality equivalent to the one in office while setting stringent cost & weight targets, and enhancing the use of environmental friendly materials.

Note: such excludes connectivity & air cabin, part of the System ITD.
The achievable level of comfort is limited by the space available in the cabin. Throughout the business jet case (combining a smaller cabin volume/section with very high expectation from the customer base), the objective is to transform the travel time into a productive/living time (meaning flight environment enjoyable & useful from the business men perception), taking into account the affordability and environmental related issues in the context of low rate production.

- First axis is to demonstrate the benefit from a deep revision of the physical layout and the volume utilisation by rethinking the functional arrangement and equipment base of a catering section.
- Second axis is to consider innovations in the diverse equipments composing the cabin interiors to offer an increased comfort, a better use of the volumes, and a flexibility of configuration in flight for the needs from the periods (sequences) of a flight.
- Third axis is to improve (weight, crashworthiness, eco-compliance, efficiency) the cabin equipments and optimize their integration to perform a global set of services, including furniture or even basic (but necessary) items like the coffee machine.
III. Technology Enablers and Demonstration Means

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<th>Key Enabling Technologies</th>
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<tr>
<td>• New seat arrangement and furniture concepts – not only for 1st and business class&lt;br&gt;• Purpose focused functionalities of cabin areas&lt;br&gt;• Local environment tailoring</td>
<td>• Dedicated digital and mock up studies&lt;br&gt;• Contribution to component and assemblies manufacturing and assembly including demonstration</td>
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**WP A-5.1 Ergonomic Flexible Cabin**

Optimal volume usage, innovation by design, light weight multifunctional/convertible seat & couch, multifunctional furniture, smart galley, novel catering equipments, flexible interior lightning, waste & wastewater management, new –eco compatible material

**WP A-5.2 Office Centered Cabin**

Full size functional mock-up of a functional zone (catering for business jet)<br>Local/partial demonstrators of novel equipments, systems or configurations

IV. Links & Interfaces

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<th>Clean Sky Background</th>
<th>Inner ITD linkage (input/outputs)</th>
<th>Inputs from</th>
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<tr>
<td><strong>Topic not addressed in Clean Sky or FP7</strong></td>
<td>With Innovative aircraft architecture&lt;br&gt;With Eco-Design&lt;br&gt;Exchanges in the component design &amp; validation cycle.</td>
<td>Configuration and requirements from overall aircraft design &amp; configuration management</td>
<td>Technology &amp; integration data to synthesis in overall aircraft design &amp; configuration management. Technologies and solutions that are being positively selected for large passenger transport to be transferred to the LPA-IADP Platform 2&lt;br&gt;Further refinement of performance data &amp; environmental footprint to Technology Evaluator and ECO design</td>
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V. High-level Plan

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<td>A - HPE</td>
<td>Novel Travel Experience</td>
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<td>Functional analysis, concept exploration, requirements definition</td>
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<td>Equipments, sub-systems developments &amp; demonstrations</td>
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<td>Mock ups</td>
<td>Integration &amp; evaluation</td>
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General notes:
1) TRL are expressed with respect to the integration at the AIRFRAME level.
2) TRL are given with respect to the main demonstration stream. Within an activity line, you can have inserted some complementary/additional technology developments that will not achieve the same TRL target.

VI. Partnerships

Aircraft OEM will perform the global trade-offs, set the requirements and together with Cabin Interiors Systems providers, will manage the integration of the demonstrators and ensure definition, development & testing of the demonstrators.

Core partners will support the development for innovation of Cabin interiors and bring contributions for cabin furniture, component & equipment design & manufacturing, advanced material, ergonomics, upholstery, packing, lights, and acoustics. Complementary supporting actions are related to Virtual design and virtual manikin & the availability of environmental friendly materials.

Design (style) institute will bring better passenger requirement capture, trends analysis and openness to a complete rethinking of volume & services arrangements.

Research Institute will provide a strong support on dedicated topics such as psycho-acoustics or bio-materials, and contribute with other specialized partners to the identification of the main parameters regulating the overall comfort in the cabin. Another focus is dedicated noise and vibration activities.
9.7 Activity Line B: High Versatility & Cost Efficiency

9.7.1 Technology Stream B-1: Next Generation Optimised Wing Box

I. Context & Objectives

The wing is a key contributor to the aircraft efficiency, and the FlightPath 2050 achievement passes necessarily through gains in the wing design targeting all the technological directions: aero-shaping, structural optimisation, system integration, cost effectiveness (manufacturing & assembly), environmental footprint reduction, etc.

For typical regional A/C and small A/C and, in general, as the vehicle MTOW diminishes and the design cruise speed is lower, the wing loading design parameter is much lower, implying that the significance of the structural size of the wing per unit payload is much higher. In addition, the accommodation of other versatile technologies on wing and the cost driver lead the wing box to be of paramount importance for the considered air vehicles in 9.7.

The challenge is to develop & demonstrate new wing concepts (including architecture) that will bring significant performance improvements (in drag & weight) while withstanding affordability & environmental stringent constraints withstand. Complementary considerations will also be put on some technology developments as common enabler to the wing efficiency, managed as a transversal, synergetic activity.

II. Scope & Added Value versus State-of-the-Art

a. Wing for incremental lift and transmission shaft integration – WP B-1.1

The compound rotorcraft introduces a major novelty by integrating a wing, with the double function to contribute to the rotorcraft lift & to integrate a propulsion system with a shaft to transfer power from the engine to the propellers hosted on the wing. The objective is to design and manufacture and substantiate a wing matching requirements of the ADP R/C LifeRCraft demonstrator and ensure verification and validation activities for delivery of that component compliant for assembly with the aircraft demonstrator, testing and flight demonstration in the scope of the IADP LifeRCraft Demo Project.

The design targets very light weight and low drag wing, enabling the full vehicle to reach challenging targets of empty weight fraction (<63%) & equivalent L/D (20% improvement w.r.t. conventional helicopter) with direct impact on speed and payload-range capability.
b. **More Affordable Composite Structures – WP B-1.2**

This WP is part of SAT activity. See description in section 12.4.1, I part.

c. **More Efficient Wing – WP B-1.3**

The objective is to develop a sound, innovative technology base for more efficient wing that could serve the different demonstrators of Airframe ITD. These technologies will relate to:

- Advanced aerodynamic efficiency, with optimal aero-shaping and passive/active flow control, external aerodynamic noise reduction...
- Novel control solutions for reduced drag
- Smart structures and efficient integration of devices & systems for drag reduction (e.g. winglet, treatment of discontinuities, cavities ... attached to mobile devices, wakes suppressions...), high lift solutions (including morphing)
- Efficient protections from the external environmental hazards (such as lightning, icing, corrosion, ...) leading to low weight, low cost, low maintenance, low energy solutions
- Lean & seamless maintenance and repair

![Figure 9.9 – A new wing: the compound rotorcraft concept introduced propelled propulsion system mounted on wing](image)

**Figure 9.9** – A new wing: the compound rotorcraft concept introduced propelled propulsion system mounted on wing

![Figure 9.11 – Morphing concepts will help to enhance the wing efficiency](image)

**Figure 9.11** – Morphing concepts will help to enhance the wing efficiency
d. Flow and shape control – WP B-1.4

The technology concepts under this WP wants to tackle the A/C efficiency in a wide range of flying conditions additional to the cruise phase by using flow control, including morphing, and to enhance the performance of the vehicle in all flight phases, including the take-off and landing. Flow and shape control are seen as the most versatile technologies to cope with these challenges.

The considered technology concepts wants also to leverage the achievements of the technologies under 9.7.1 regarding the wing box by using loads control concepts like aero-elastic tailoring for passive loads alleviation and active loads control. These technology are seen as cost effective technologies to mitigate one of the most impacting aspects on regional A/C wings and small air vehicles which is the structural size of the wing, as said in 9.7.1.

This axis of investigation aim to enhance the wing design (weight reduction) thanks to load alleviation achieved with a combined approach of flow control, in flight shape adaptation (morphing) and of flight control. The key targeted achievements are:

- To reduce the structural weight;
- To reduce the aerodynamic drag in all the flight phases;
- To improve the aircraft performances in takeoff and landing reducing at the same time the noise;
- To improve safety with a more protected aircraft in terms of aerodynamic loads.

The technological path will be:

- The use of morphing concepts to optimize the drag in any phase of the flight;
- The use of morphing concepts in combination with classical primary controls to reduce the loads at the wing root;
- The use of flow control in low speed to reduce the parasitic drag at different locations of the aircraft;
- The use of flow control to improve the lift performances and noise emission in landing and takeoff;
- The application of aero-elastics concepts and flow control to the loads control, to reduce the wing weight.
## III. Technology Enablers & Demonstration Means

<table>
<thead>
<tr>
<th>Key Enabling Technologies</th>
<th>Key Demonstration Vehicle</th>
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<tbody>
<tr>
<td><strong>Advanced structural design</strong></td>
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<tr>
<td><strong>Wing For Incremental Lift And Transmission Shaft Integration</strong></td>
<td>Full scale wing and flap, one article to be delivered for the Iron Bird (mechanical test bench), another article to be delivered for flight demonstrator assembly (shake test and flight campaign); Full range of calculation and simulation tools (CFD, FEM, dynamics); sample, sub-components and full component ground tests; substantiation documents for Permit-to-Fly. TRL 5 with Airframe ITD; TRL6 after flight demonstration in IADP R/C LifeRCraft project.</td>
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<tr>
<td>• CFD optimization of aerodynamic design (airfoils, flaps, 3D) for full aircraft L/D. Wing-fuselage and wing-propeller integrated design. TE flaps ensuring incremental lift control with minimal drag impact and allowing to reduce wing blockage of rotor downwash in hover;</td>
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<td>• Design-to-stiffness, aero-elastic tailoring to prevent whirl flutter and resonance;</td>
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<td>• Advanced structural design i.e. topologic optimization and smart combination of composite and metallic materials;</td>
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<td>• Study to consider interest of WIPS; if confirmed, provision for integration (no development);</td>
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<td>• Transmission shaft and harness integration for high integrity; full tank integration (optional);</td>
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<td>• Green materials, low energy &amp; low scrap production processes (fiber placement, out-of-autoclave curing), reparable &amp; recyclability</td>
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<td>• Design to Cost (NC, DMC)</td>
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<tr>
<td><strong>More Affordable Composite Structures</strong></td>
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<tr>
<td>Investigation of the possibilities of application of modern <strong>out of autoclave</strong> technologies like low pressure and low temperature pre-preg and liquid infusion methods in the area of production, also enabling easy in-field repair possibilities.</td>
<td>Design and manufacturing of a substantial part of a composite wing as an example for a main aircraft structures, static test including health monitoring, leading to TRL level 5-6 validation</td>
</tr>
<tr>
<td>Investigation of the possibilities of application of higher temperature resistant resin.</td>
<td>Secondary aircraft structures nacelle designed and manufactured with the aim of low cost and weight, static test, fire resistance test, leading to TRL level 5-6 validation</td>
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<tr>
<td>Improvement of <strong>automation during production process</strong> of composite structures.</td>
<td>Static testing of Floats aircraft structure manufactured in hybrid materials leading to TRL level 5-6 validation</td>
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<td>Investigation of the possibilities of application of hybrid</td>
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<tr>
<td>Key Enabling Technologies</td>
<td>Key Demonstration Vehicle</td>
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<tr>
<td>Application of modern thermoplastics for secondary aircraft structures using the better impact and damage tolerant capabilities compared to composite material.</td>
<td>Partial demonstrator for wing testing, in particular Wind Tunnel. Possibly, according to preliminary studies, in flight demonstration of local/basic technology.</td>
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**Advanced Wing Technologies**

### More Efficient Wing
- CFD and multidisciplinary approach
- Aero-shape optimization
- Morphing technologies
- Flow control
- Flow control for winglet
- Winglets and wing plant optimization
- Enhanced EMI EMC protection, lightning protection
- Anti-icing coatings
- Multifunction coatings
- Repair technologies
- Health monitoring, health assessment

#### Flow Control
Advanced CFD & flow control technologies applied to delay or mitigate the flow detachments
Morphing concepts for the loads control
Aerodynamics and aero-elastic concepts for the passive loads control
Active loads control using classical primary and innovative controls in combination with functionalities in the FCS

#### Flow & Shape Control
- Demonstration in Wind tunnel test with scaled models
- The combined structural concepts and aerodynamics concepts with full scale models will be demonstrated in flight test in the R-IADP
## IV. Links & Interfaces

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<th>Clean Sky Background</th>
<th>Inner ITD linkage (input/outputs)</th>
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<tr>
<td>GTC2 : reduction techniques &amp; engine integration; TP composites Achievements of Clean Sky GRA FP 7 projects for small aircraft : CESAR, SAT roadmap</td>
<td>With new materials &amp; advanced manufacturing With all wing developments Exchanges with the fuselage structural developments Exchanges in the component design &amp; validation cycle.</td>
<td>Configuration and requirements from overall aircraft design &amp; configuration management Specifications &amp; interfaces from the R/C LifeRCraft IADP &amp; R-IADP.</td>
<td>Technology &amp; integration data to synthesis in overall aircraft design &amp; configuration management. Footprint data to Eco-Design assessment Laminarity technologies &amp; wing Substantiation of a wing matching requirements of the associated demonstrator component to the R/C LifeRCraft IADP.</td>
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V. High-level Plan

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<td>B-HVE</td>
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<td>Development &amp; Manufacturing</td>
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<td>Ground demo testings</td>
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General notes:
1) TRL are expressed with respect to the integration at the AIRFRAME level
2) TRL are given with respect to the main demonstration stream. Within an activity line, you can have inserted some complementary/additional technology developments that will not achieve the same TRL target

VI. Partnerships

Aircraft OEM will perform the global trade-offs, set the requirements, manage the integration and, when appropriate, ensure the proper interfacing to the IADP. They will bring key contributions to the definition, development & testing of the demonstrators, based on their expertise in design and manufacturing expertise of advanced composite structures.

Core partners from aero-structure industry will contribute for part design & manufacturing, composite technologies & hybrid structures (mix of composite & metal in a structure), new materials, material coupon testing, ground (static & dynamic, including wing static test) testing. Knowledge & capabilities are also required for automated composite manufacturing and advanced production processes & tools.

Research Institute will bring their expertise in modelling (CFDs, static & dynamic analysis, lightning, ice accretion, materials, manufacturing process, fatigue ...) and advanced testing techniques and means (i.e. wind tunnel tests).

Integrated aero-structure manufacturer could also developed competitive approach for composite optimisation throughout dedicated demonstrator of complex aero-structure wing assembly, in order to explore other alternative option.
9.7.2 Technology Stream B-2: Optimized High Lift Configurations

I. Context & Objectives

Turbo Propelling will stay attractive to a green Regional Aircraft: they have a very good fuel efficiency which positively trade-offs their limitation in speed for short/medium hauls (gains in speed are less spectacular in term of time efficient for a short haul, when its critical to a long haul). Nevertheless, the architecture of next generation of Turbo Propelled shall dramatically evolve to improve wing performances, nacelle qualities and to efficiently accommodate larger, more efficient engine and to sharply improve the integration quality compared to the current in service generation, gaining in weight, drag and energy management.

II. Scope & Added Value versus State-of-the-Art

a. High wing / Large TurboPropeller engine integration – WP B-2.1

The focus will be on efficient architectural concepts for advanced structural design of Nacelles Airframe integration by means of multi-disciplinary approach.

New architectures will be investigated to optimize nacelle & propeller installation and attachment to the wing, efficiently accommodating next generation nacelle concepts:

- With weight reduction using constructive concepts;
- With improved combination of propulsion and ventilation concepts that pursuits a more efficient ventilation in all the engine and propellers regimes at the same time;
- With drag reduction optimizing the external nacelle shapes in combination with the wing shapes to pursuit the minimization of the drag and to avoid any detrimental effect in the high lift performances;
  - The new external nacelle shapes are optimized
  - The new internal nacelle shapes for the intake and exhaust are optimized to secure optimal operation of the new engine generation in all operation conditions. Flow control techniques can be also employed for this purpose.

This activity will be the global architectural input to the concepts developments for optimized integrated nacelle & high lift wing for Turbo propelled aircraft performed in this Technology Stream.

Figure 9.12 – Novel engine mountings will enable more efficient engine integration to the wing

The multidisciplinary discipline approach will enable to integrate the different objectives regarding:
Clean Sky 2 Joint Technology Initiative in Aeronautics

- Engine Mounting
- Cowling development:
  - Ventilation (Aero-Systems)
  - Structure (Architecture, Material & Manufacturing Process, Fire resistance, etc.)
  - Systems development & integration
- Nacelle-Engine integration
- Engine Air intake (low power ice protection)

Inputs from National Research Projects will be consolidated to reach higher TRL levels, focused on flight consolidation aspects.

Research on different engine mounting architecture with different materials and joints configuration should help to reduce the overall weight, vibration diffusion through the rest of the structure optimizing general a/c performance and reducing the vibration requirements for equipments installed around power plant or at location influenced by the engine. Complementary objectives deal with designing and producing enhanced mounting to be installed as part of advanced CFRP flight demonstrator wing able to accommodate different type of engines to evaluate flight performances in combination with power plant energetic efficiency.

Based on experience of EADSCASA products and A400M a new set of cowling lighter in terms of weigh/unit of area should be substantiated accounting for those systems usually integrated in the cowling (anti-ice, fire-extinguish and ventilation control devices, etc.).

Structural wise, the cowling will cover optimized architecture design (accounting for ventilation assessment) and manufacturing, selection of material, virtual testing of manufacturing & qualification aspects including fire resistance to be validated by testing carried on coupons & panels. Other aspects dealing with noise and vibration absorption, lighting strike and impact protection will be tackled into the design through the exploration of requirements and verification of goals. More integrated manufacturing process with more efficient and advanced materials will be explored. In addition, enhanced analysis methods together with design allowable determination & certification approaches should be investigated.

As a matter of fact and due to the flight clearance requirements, enhancements on structural protection safety systems should take place as part of the engine-nacelle integration.

This should results in a significant fuel saving and consequent reduction of CO₂ emissions at least equivalent to 8% weight saving for similar volume power plant (foreseen unpredicted reduction per HP of power plant designed for).
b. **High Lift Wing – WP B-2.3**

The scope is to develop advanced technologies for high lift wing, increase the lift performance of the overall wing at low speed focusing on larger wing aspect ratio and high lift systems, advanced structural architecture including systems integration and more integrated torsion box manufacturing process with more efficient and advanced materials to produce more efficient ecological footprint. Weight savings vs improved overall functionalities will be convened to be design drivers. On this respect, different OoO manufacturing process will be matured to produce composite structures for uppers skin, lower skin and spars. Other structure as wingtip or leading edge will integrate as far it becomes functionally effective new morphing concepts compatible with manoeuvre load alleviation characteristics. High lift devices will be developed with increased performances compatible with the type of “multi leg flight profile” a/c being explored.

All these aspects will design to be compatible with higher integration of general systems and fully compatible with advanced hybrid health monitoring system useful for metallic and composites prognostic and diagnostic applications.

In addition, more accurate analysis methods, allowable determination, and certification approach will be developed.

The concept of high lift wing to be developed is in line with the objectives of the Regional Aircraft to be tested in IADP RA FTB2 i.e. optimised to multi points operations and short runways. All structural development for wing and high lift system will be developed and ground tested within the Airframe ITD. A final component will be developed to be integrated in the RA IADP for flight test.

The direct targeted benefits are:

- Wing featuring low stall speed, increasing then the aircraft versatility thanks to excellent field performances, serving the flexible mobility of regional aircraft or general aircraft. Field performance is dominated by the propulsion (takeoff) and even more important by the reference speeds $V_2$ (takeoff safety speed) and $V_{REF}$ (landing reference speed). Both speeds are mostly based on multiples of the stall speed which is again driven by the maximum lift capabilities of the wing;
Reduction of manufacturing cost due to higher integration;
Weight reduction due to multidisciplinary optimization including new certification approach that should allow to achieve a significant fuel saving and consequent reduction of CO₂ emissions at least equivalent to 8% weight saving.

Wing design currently in flight for regional a/c deals with co-bonded skin to spars or stringer structures for aspect ratios < 10. The proposed wing demonstrator will be:

- Aspect ratio in the order of 12
- High level of system integration, including advanced solutions for More Electrical Aircraft, high lift devices or systems and structural HM for damage detection and monitoring
- Advanced high lift system optimized for multimission take off and landing design points
- High part integration for the skin to spars & stringers manufacturing process
- “2-Half “wing skin with spars & stringers manufactured in “one-shot process with metallic ribs installation in subsequent assembly
- Optimized of wing attachment fittings for local high load points, flaps, engine mounting, control devices.....
- Reducing of the assembly tasks

Conceptual design must be fully compatible with technological research regarding advanced aero-elastic for an optimization of the profile and wing geometry, tailoring the design details and structural concepts. The architecture analysis and concept design to be performed here will take direct advantage from the innovations and advanced solutions explored in some others technology streams: the engine integration explored for high wing with large turbo-propellers, the laminarity developments, some key features of the more efficient wing technologies (winglets, high lift devices, morphing, ...) and the advanced integration of systems in the wing. The studies and developments will take particular attention to the delivery of an integrated concept, capable of embarking all this new technologies, as a major enabling demonstration of a future efficient wing to be evaluated at aircraft level in the Regional IADP.

The High Lift wing technologies will also help for achieving the goals for future new generation small transport aircraft using the full CS23 commuter weight range. Such requires improvement of the high lift capabilities to keep the stall speeds and the subsequent reference airspeed and field performance on the same level of available aircraft types with lower weights. The goal is to improve the high lift capabilities based on simple and cost effective system(s) which do not adversely affect the high speed performance and more important the overall aircraft cost structure. See section 12.4.1, II part for details.
### III. Technology Enablers & Demonstration Means

<table>
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<tr>
<th>High Wing / Large Turbo-Propeller Nacelle Configuration</th>
<th>Key Enabling Technologies</th>
<th>Key Demonstration Vehicle</th>
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<tbody>
<tr>
<td>– Novel architecture design of propulsion integration on high wing</td>
<td>Analyses – CFD</td>
<td>Wind tunnel tests</td>
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<tr>
<td>– New ventilation concepts and nacelle shapes</td>
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<tr>
<th>Optimized Integration Of Nacelles For Turbo Propelled Aircraft</th>
<th>Key Enabling Technologies</th>
<th>Key Demonstration Vehicle</th>
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<tbody>
<tr>
<td>– Advanced architecture conceptual development</td>
<td>The objective is to demonstrate the overall nacelle concept with a set of individual testing, then validation on a partial, representative assembly of components, including system integration, up to rig tests and ground test targeting integrated nacelle concepts to be tested in flight in R-IADP:</td>
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<tr>
<td>– High Integration of hybrid components: metallic and composites</td>
<td>• Simulation &amp; virtual testing</td>
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<td>– Use of multifunctional materials within new conceptual laminates with improved mechanical, acoustic, thermal, electrical, impact protection and anti-erosion behaviour</td>
<td>• Manufacturing trials of panels &amp; structural details</td>
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<tr>
<td>– Multidisciplinary design harmonization</td>
<td>o Tooling design and manufacturing</td>
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<tr>
<td>– Methodology development for simulation, virtual &amp; real testing</td>
<td>o Inspections &amp; repairs</td>
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<tr>
<td>– Systems-structure integration</td>
<td>• Coupôns &amp; panels test</td>
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<td>o Assessment of systems functionalities</td>
<td>• Components manufacturing (one hand mounting and cowlings) for non destructive testing research. Assembly and rigging of 1\textsuperscript{st} Article</td>
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<td>– Repairs feasibility and qualification</td>
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<td>• Integration &amp; assembly of systems. Verification of accomplishment of structural and systems requirements &amp; interfaces</td>
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<td>• Substantiation of systems performances &amp; functionalities through ground testing</td>
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<td>Key Enabling Technologies</td>
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<tr>
<td><strong>High Lift Wing</strong></td>
<td>Wind tunnel tests of 1/12 and ¼ scale wind tunnel models of future small green aircraft in the commuter category</td>
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<tr>
<td>• Advanced Structure concepts, OoA composites manufacturing and testing</td>
<td>Regional aircraft wing full scale ground demonstrator including:</td>
<td></td>
</tr>
<tr>
<td>• SHMS continuous development and substantiation</td>
<td>• Analysis of performance &amp; aerodynamic potential benefits from different perspective (includes simulation)</td>
<td></td>
</tr>
<tr>
<td>• Technologies of active or passive means of lift increasing devices</td>
<td>o Flight physics assessment and analysis – CFD and wind tunnel</td>
<td></td>
</tr>
<tr>
<td>• Wing Leading edge Morphing – including actuation by EMAs providing the basis for the integration of anti-ice systems</td>
<td>o Structural &amp; weight (includes bird strike)</td>
<td></td>
</tr>
<tr>
<td>• Winglets morphing - structural devices that might be optimally adapted to different flight conditions through relatively minor shape alteration induced by relative displacement of trailing edge.</td>
<td>o Manufacturing (includes spring back)</td>
<td></td>
</tr>
<tr>
<td>• Adaptive High Performance high lift devices</td>
<td>• Development of SHM application</td>
<td></td>
</tr>
<tr>
<td>• Drag reduction including Improved laminar flow</td>
<td>o Transducers selection</td>
<td></td>
</tr>
<tr>
<td>• Active Load protection</td>
<td>o Signals data fusion</td>
<td></td>
</tr>
<tr>
<td>• Improved high wing nacelle and power plant integration - The objective is to develop a new cowling concept with significantly lighter in terms of weight/unit of area with respect to the current PWP nacelles. The new cowling will take advantage of new materials with higher allowable temperatures and new architecture to improve ventilation aspects around the engine accounting for enhanced sealing proposals to accomplish with fire extinguishing requirements.</td>
<td>o Discrimination and diagnosis</td>
<td></td>
</tr>
<tr>
<td>• Power plant and wing nacelle integration including new fire resistant materials</td>
<td>• Assessment of anti-ice system integration</td>
<td></td>
</tr>
<tr>
<td>• Suitability of structural models/results for aerodynamic simulation usage</td>
<td>• Manufacturing trials of scaled component</td>
<td></td>
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<tr>
<td></td>
<td>o Tooling design and manufacturing</td>
<td></td>
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<td></td>
<td>o Inspections &amp; repairs</td>
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<tr>
<td></td>
<td>• Development of the structural concept &amp; manufacturing of structural elements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Assembly and rigging of 1st Article</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Ground Test Program (coupons, subcomponents, wing test article, etc.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Flight test of wing and high lift system components to be done in RA IADP with the components developed in AF ITD</td>
<td></td>
</tr>
</tbody>
</table>
## IV. Links & Interfaces

<table>
<thead>
<tr>
<th>Clean Sky Background</th>
<th>Inner ITD linkage (input/outputs)</th>
<th>Inputs from</th>
<th>Outputs to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional Aircraft concepts</td>
<td>With Innovative aircraft architecture</td>
<td>Configuration and requirements from overall aircraft design &amp; configuration management</td>
<td>Requirements (performances &amp; interfaces) to engine &amp; system ITDs, inclusive of integration requirements to electrical systems</td>
</tr>
<tr>
<td>GTC2:</td>
<td>With new materials &amp; advanced manufacturing</td>
<td>Specifications &amp; interfaces from the R-IADP.</td>
<td>Technology &amp; integration data to synthesis in overall aircraft design &amp; configuration management.</td>
</tr>
<tr>
<td></td>
<td>Exchanges with the fuselage structural developments</td>
<td>System ITD for health monitoring systems, anti-icing systems, electrical control systems</td>
<td>Footprint data to Eco-Design assessment</td>
</tr>
<tr>
<td></td>
<td>Exchange with integrated structures works</td>
<td></td>
<td>Demonstrator component &amp; wing substantiation to R-IADP</td>
</tr>
<tr>
<td></td>
<td>Exchanges in the synergetic efficient wing technologies transverse activities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exchange with Advanced Laminarity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achievements of Clean Sky GRA along with links that may be identified in some FP7 L1 - L2 research programs (AEROMUCO, EXTICE, etc.)</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
V. High-level Plan

|------|----|----------|------|------|------|------|------|------|------|------|------|
| B - HVE | Optimized high lift configurations |  | TRL 3/4 | TRL 4 |  | TRL 5/ Components validated for IADP integration &
|  | Studies |  |  |  |  |  |
|  | Desing & Development |  |  |  |  |  |
|  | Manufacturing |  |  |  |  |  |
|  | Testing & Validation |  |  |  |  |  |

General notes:
1) TRL are expressed with respect to the integration at the AIRFRAME level.
2) TRL are given with respect to the main demonstration stream. Within an activity line, you can have inserted some complementary/additional technology developments that will not achieve the same TRL target.

VI. Partnerships

Aircraft manufacturer (OEM) will perform the architectural works, concept definition & synthesis, based on their experience & knowledge on overall design. They perform the global trade-offs, set the requirements, manage the integration and ensure the proper interfacing to the IADP. They will bring key contributions to the definition, development & testing of the demonstrators, based on their expertise in design and manufacturing expertise of advanced composite structures.

Engine manufacturer (OEM) will contribute as core partners to the relevant integration studies, engine concepts analysis and engine performance assessment.

Core partners from aero-structure industry will contribute for part design & manufacturing, composite technologies, new materials, material coupon testing, ground (static & dynamic, including wing static test) testing. Knowledge & capabilities are also required for automated composite manufacturing and advanced production processes & tools.

The European aeronautics supply chain will be also involved for thermoplastic engine nacelles & hybrid structures (mix of composite & metal in a structure) activities.

Equipments/Sub-systems providers will fit their innovative component in the wing structure when appropriate for integration demonstration purposes.

Research Institutes with excellent track record in physical simulations & advanced testing will contribute with focused advanced modelling & computational analysis, and use of their large test infrastructures (WTT) and reference data base and models. Contributions from partners with capacities to design, manufacture and test aircraft wind tunnel models are also expected.

Possibly, the exploration of some most disruptive, far-fetched configurations could be explored by Research Institutes. Integrated aero-structure manufacturer could also developed competitive approach for composite optimisation throughout dedicated demonstrator of complex aero-structure wing assembly, in order to explore other alternative options.
9.7.3 Technology Stream B-3: Advanced Integrated Structures

I. Context & High-Level Objectives

Progress in structural design is required to complement by airframe’s weight savings the performances gains from the wing and global aero-shaping optimization. Such can be made possible in particular by achieving structural improvements thanks to a global optimization of the integration of systems & equipments in the airframe. Such includes addressing the new integrations challenges brought by the more electrical systems technologies.

Taking into account the market & price pressure increases with the stringent combinaison of of price pressure from new competitors and high level of expectations from the eco-compliance, airframe structure progresses shall come with competitiveness improvements in the manufacturing and assembly processes, to enable the future airframe enhancements, but at affordable conditions, creating the favourable environment for market insertion of optimised structures in weight & cost. Therefore the Eco-Design and structural design progresses shall come with progress in the production efficiency and competitiveness. Such should apply to all airframe technologies, metallic or composite, fuselage or wing or cockpit structure, etc.

Figure 9.14 – The hybrid cockpit demonstrator is an example of architecture re-thinking to optimize the structural design thanks to advanced structure/systems integration

II. Scope & Added Value versus State-of-the-Art

a. Advanced Integration of Systems in Nacelles – WP B-3.1

Advanced integration of systems and of components will bring better energy management, aerodynamic efficiency, improved noise containment and weight reduction, in particular thanks to:
- More efficient integration of electric anti-ice systems in high temperature composites, hence weight reduction and power saving
- Noise reduction both in inlet and nozzle/thrust reverser
- Noise reduction and ice protection system integration to extend Nacelle inlet ice protection to the acoustic liners covering also Super Large Droplets encounters
- Aerodynamic performance enhancements

The technology implemented in the demonstrators will:
- Prove composite lip concept vs. Heating and bird strike
- Enable to obtain composite laminar flow inlets, finally resulting in less fuel consumption
- Enable investigation on distributed low power anti/de icing systems, finally resulting in less fuel consumption
- Expand the capacity to predict and attenuate Engine sourced noise, finally resulting in quieter airplane both for ground noise and cabin noise in order to contributing to the achievement of ACARE 2020 Targets for noise reduction
- Expanding and tailoring the band of attenuated Engine Noise
- Allow experimental validation of aeroacoustics models for high performance noise attenuation systems that is currently not available
- Experiment and validate emerging concepts for active noise suppression
- Provide the possibility to design low temperature anti-ice systems which can comply with severe icing conditions, including SLD, finally resulting in increased safety and less fuel consumptions
- Increase the noise reduction treatment towards the lip, finally allowing low noise operations
- Allow a greater integration within noise reduction system and anti-icing system, finally aiming at a more modern architecture, lighter and simpler.

b. **All Electrical Wings – WP B-3.2**

By the elimination of one or more hydraulic and pneumatic system, the major expectations from a More/All Electrical Aircraft architecture is to are, among others:
- To Save **Weight And Contributes To Less Fuel Consumption, And Then Less Contaminant Emissions**;
- To Remove **Non Environmental Friendly Fluids** From The Aircraft
- Simplify The Architecture And **Improve The Reliability And Maintainability**

Aside from the development of a novel generation of high performance electrical systems and power generation systems, the integration of the new electrical equipment is one of the remaining bottleneck, as well from the installation point of view and the impact on the shape and aerodynamic point of view, but also from thermal environment, vibration environment or even accessibility points of views...

The objective is to develop the technology to be able to integrate into the Airframe the All Electrical Aircraft technologies, including Systems and Integration technologies in particular related to the aircraft wing. In *Clean Sky*, the SFWA, GRA and in particular the SGO have develop All or More Electrical Aircraft specific technologies which will be analyzed, integrated into a demonstrator bench and the TRL evolved in terms of their integration aspect into the airframe and finally into the aircraft. The group of technologies from *Clean Sky* will be complemented by the activities of the system ITD that will deliver electrical components/equipments for further integration in the wing.

The different applicability to the different types of aircraft will be analyzed considering the specificities for their use in the IADPs.

Namely the integration of the following technologies:

- Control surface actuation systems – EMAs: Demonstrate and consolidate the use of EMA on wing flight control surfaces with more severe high level requirement that considered in Clean Sky 1 level such as high duty cycles, system criticality etc. 270V will be considered as a source of weight reduction.
- Enhanced high lift devices
- Electric actuators for morphing and primary control surfaces. Provide electrical actuation to morphing/tabs to be used in morphing surfaces as well as tabs to be used in the loads control system.
- Low power ice protection system: Electrical anti ice systems including a high degree of structural integration in order to minimize weight while maximizing system efficiency.
- Integrated low profile SATCOM antenna: The innovation step of this activity is a system conformal and distributed into different airframe structures aiming to eliminate the aerodynamic drag issues and to improve system performances. Also, the integration concept of antenna system elements within airframe structure presents a high innovative and technological component since it must fulfill simultaneously structural and system functionalities.

c. **Highly Integrated Cockpit – WP B-3.3**

The advanced integrated cockpit targets both significant improvements in the structure design that will result in a significant fuel saving and consequent reduction of CO₂ emissions of at least equivalent to 8% weight saving, and significant reduction of the production cost. Key expected benefits are:

- Reduction of manufacturing cost due to higher integration
- Weight reduction due to multidisciplinary optimization including new certification approach
- Enhancement of new multifunctional materials.
- Manufacturing and assembly skill and capabilities; Structural dynamic and structural analysis tools

The activity is a step beyond the *Clean Sky* GRA Light Weight Cockpit: not only overcoming the flight clearance limitation identified in the ground full scale advanced composite cockpit demonstrator under development into the GRA *Clean Sky*, the advanced integrated cockpit for *Clean Sky 2* will continue the activities in terms of internal noise with respect to the external noise source (potentially translated in less acoustic isolation), additional structural research regarding impact protection induced by hail or debris among other sources. This will be complemented with enhancements of software development to enable bird and lightning strike simulations on hybrid cockpit hopefully tuned with test results. As a natural complement, research on bonding repairs of multifunctional laminates will continue, in addition, to novel repair technologies for composite materials that are foreseen being developed.

SHMS conceptual approach started on *Clean sky 1* will continue its development supported by corresponding testing on available cockpit demonstrators or additional structural components being manufactured for such purpose.

One of the key novel features will be the integration of the Cockpit Systems (as much as possible and depending on the availability of technologies) including all additional requirements in terms of electrical continuity, EMI/EMC protections by using Ferromagnetic micro wires into Carbon Fiber structural elements, along with the validation of important structural advances. This high level of integration will lead to total integrated weight and cost savings.

Part of the systems to be analysed will be the nose landing gear, in which innovative technologies for structural health monitoring or advanced electrical damping systems will be investigated.

The advanced integrated cockpit will benefit from more integrated manufacturing processes with more efficient and advanced materials combined with more accurate analysis methods, allowable determination and certification approach. On the basis of existing cockpit demonstrators, enhancement of current structural architecture will take place being supported by correspondent physical or virtual testing and bearing in mind new and updated systems integration requirements.

Research on multifunctionality carried on primary structure will be enlarged into the secondary structure and thermo-acoustic isolation elements to improve the overall cockpit performance.
Availability of cockpit demo will be used, as far it becomes feasible and practical, to test multipurpose conformal antennas. Architecture will be rearranged according to correspondent systems requirements.

d. **More Affordable Small a/c Manufacturing – WP B-3.4**

This WP is part of SAT activity. See description in section 12.4.1, IV part.

e. **Advanced integration of systems in small a/c - WP B-3.5**

This WP is part of SAT activity. See description in section 12.4.1, V part.

f. **New Materials & Manufacturing – WP B-3.6**

The main objective is to develop manufacturing & assembly technology base applicable to the different demonstrator paths. Such shall contribute to the achievement of the optimal, low weight structures targeted in Clean Sky 2, with a cheaper and easier production and maintenance, in compatibility/compliance with the Eco-Design developments to be done in a synergetic fashion in Airframe ITD.

To achieve this objective, the following axes are to be developed:

- Reduction of overall a/c manufacturing costs, in terms of time and resources
- Increase of manufacturing automation, for both resource management, and reproducibility/quality control point of views
- Increase of manufacturing process flexibility
- Reduction of time to market
- Development of new materials and their corresponding assembly techniques
- Development of novel and advanced manufacturing process & assembly techniques.
III. Demonstration activities

Demonstration activities will be based on the achievements of particular WPs:

Demonstration S.1 - Efficient operation of small aircraft with affordable health monitoring systems

- Onboard health monitoring technologies addressed in WP S.1 for SAT aircraft will be tested both in laboratory and on aircraft platforms. The health monitoring capabilities will be developed and demonstrated on selected A/C components. Preliminary component selection includes Horizontal Stabilizer Trim Actuator and Landing Gear Actuator. The local diagnostic units are supposed to be demonstrated as a part of overall IVHM system.
- Expected target TRL for on board health monitoring technologies developed in this WP is 5/6.
- The objective is to develop a dedicated IVHM to be installed on in service (or prototype flying) aircraft in order to monitor some key components.

Demonstration S.2 - More electric/electronic technologies for small aircraft

- More Electric/electronic technologies addressed in WP S.2 for SAT aircraft will be tested both in laboratory and on aircraft platforms.
- Test on aircraft platform will both on ground and in flight; expected target TRL for more electronic/electric technologies developed in this WP is 5/6.

Demonstration S.3 - Fly-by-wire architecture for small aircraft

The demonstrations of FBW for small aircraft will be organized in layered way. Three layers of demonstrations will be performed which will demonstrate different capabilities/functionalities of FBW starting on FBW module level, then on aircraft level and finally on air transport level:

- Demonstration of a representative FBW configuration for small aircraft on an iron bird stimulated by a closed loop simulator:
  - Cost efficient high reliable FBW modules (computing, input-output, actuators, power distribution);
  - FBW redundancy management;
  - FBW network communication;
  - FBW mechanical retrofit modules for easy aircraft integration.

- Demonstration of basic FBW functionality during flight tests on a small aircraft (increased safety by flight envelop protection):
  - Manual flight with digital stick/lever;
  - Auto pilot/Automatic flight;
  - Automatic take-off and landing.

- Demonstration of integration of FBW functionality in highly automated ATC/ATM environment during flight tests on a small aircraft (increase of safety by airspace violation avoidance, integration into SESAR):
  - Manual flight with easy handling characteristics;
  - Automatic execution of 4D SESAR business trajectories;
  - Emergency safe return.
In parallel guidance material for FBW development, certification, and operations will be prepared together with CAAs which will allow extending CS23 to FBW operations (similar as done for CS25 in the past).

**Demonstration S.4 - Affordable SESAR operation, modern cockpit and avionic solutions for small a/c**

- Affordable SESAR operation, modern cockpit and avionic solutions for small a/c will be demonstrated on System Integrated Lab with implemented new Glass Cockpit as well as some solutions will present on real platform such as M28 aircraft and other similar.
- Laboratory tests and tests on real aircraft platform (ground and in flight) for affordable SESAR operation, modern cockpit and avionic solutions for small a/c technologies developed in this WP shall be estimated at TRL levels 4-6.

**WP S.5 - Comfortable and safe cabin for small aircraft**

WP will be demonstrated on:

- Multifunction thermo-acoustic cabin interior together with will smart passive damping devices and noise active control system reducing significantly vibration and noise in the fuselage structures and decreasing energetic needs of the cabin;
- Passenger individual comfort ensured by appropriate management of cabin airflow and temperature using innovative analytical approaches, bleedless low-energy ECS air distribution and recuperation, control of air quality during flight and operation from unprepared airstrips (separators, filters, air quality monitoring);
- Embedded communication network solutions fitted to satisfy customers expectations. Design goals consider the specifics of general aviation market through an efficient and lightweight hardware design utilizing price competitive COTS components;
- New generation of lightweight comfort crashworthy seats in slim configuration adaptable to different requirements of airframers (seat track pitch, floor/wall mounts, padding shapes, IFE systems, hand luggage storage).

Coupon, stand and dynamic tests are planned in the course of development; results will be integrated into an aircraft demonstrator at TLR 5-6 and tested in flight.
### IV. Technologies

#### Key Enabling Technologies

<table>
<thead>
<tr>
<th>Integrated Structures</th>
<th>Key Demonstration Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WP B-3.1 Advanced Integration Of Systems in Nacelle</strong></td>
<td>Validation with final testing of full scale system demonstrator.</td>
</tr>
<tr>
<td>• High temperature / impact resistance composites</td>
<td>• For Electric Anti-Icing System A 3D IWT Test Item For Large Scale Icing Wind Tunnel Campaign Is Foreseen</td>
</tr>
<tr>
<td>• Highly coupled engine airframe integration</td>
<td>• Acoustic Technologies And Models Will Be Demonstrated Via The Realization And Testing Of Full Scale Wide Frequency Absorbing Acoustic Panels For Anechoic Chamber Measures</td>
</tr>
<tr>
<td>• De-risking highly integrated airframe structures at competitive cost</td>
<td>Integration Of Heating Systems Into The Acoustic Treatments Will Be Demonstrated With 2D Icing Wind Tunnel Test Campaign.</td>
</tr>
<tr>
<td>• Power management and electric anti-ices – synergies with engine &amp; systems ITDs</td>
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<tr>
<td>• Safety assurance in all normal/failure operating conditions</td>
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<tr>
<td>• Advanced sensing system / power control</td>
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<tr>
<td>• Operational validation of active (flow control) and passive (high DoF) liners for noise reduction</td>
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<tr>
<td>• Structural integrated ducts and manufacturing challenges for impedance matching</td>
<td></td>
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<tr>
<td>• Heating systems</td>
<td></td>
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<tr>
<td>Power reduction techniques and energy/heat management (SHS, wettability control, heat pipes, ...)</td>
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</tbody>
</table>

#### WP B-3.2 All Electrical Wing

<table>
<thead>
<tr>
<th>Validation with final testing of full scale system demonstrator.</th>
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<tbody>
<tr>
<td>• For Electric Anti-Icing System A 3D IWT Test Item For Large Scale Icing Wind Tunnel Campaign Is Foreseen</td>
</tr>
<tr>
<td>• Acoustic Technologies And Models Will Be Demonstrated Via The Realization And Testing Of Full Scale Wide Frequency Absorbing Acoustic Panels For Anechoic Chamber Measures</td>
</tr>
<tr>
<td>Integration Of Heating Systems Into The Acoustic Treatments Will Be Demonstrated With 2D Icing Wind Tunnel Test Campaign.</td>
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</table>

<table>
<thead>
<tr>
<th>The demonstrations conducted here are the first step of a 3 folds validation logic :</th>
</tr>
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<tbody>
<tr>
<td>• Validation in bench facilities,</td>
</tr>
<tr>
<td>• Icing wind tunnel</td>
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<tr>
<td>• then integrated &amp; tested into the high lift wing demonstrators part of the more efficient wing activities in the Airframe ITD</td>
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<tr>
<td>• and finally tested into the Flying Test Beds in the framework of the R-IADP</td>
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</tbody>
</table>

**Successful completion of the bench testing, ground and then the flight testing will allow launching further projects intended to industrialize solutions aiming to widening the use of these architectures.**
### Key Enabling Technologies

**WP B-3.3 Highly Integrated Cockpit**

- Advanced structural architecture and systems integration taking into account the system installation and manufacturability aspects. Improvements in wiring leading to reduction of complexity (configuration control, safety) and weight.
- High Integration of hybrid components: metallic and composites – system installation optimization from modularity and use of advanced concepts (Optical fiber, wireless, etc).
- Use of multifunctional materials within new conceptual laminates with improved mechanical, acoustic, electrical, impact resistance and anti-erosion behavior. Enlargement of conceptual design into secondary structure and isolation elements.
- Assessment of systems functionalities. Statement of additional requirements.
- New concepts repair prototyping.
- SHMS functionality demonstration.
- Integrated System electrical functionality demonstration.

**WP B-3.4 Advanced integration of systems in small a/c**

Advanced system technologies developed in ITD System and focused on reduction of the Operational Costs, improved cabin (noise, thermal, entertainment) & flight comfort and safety and security.

### Key Demonstration Vehicle

The demonstrator will be a full scale advanced materials hybrid integrated cockpit demonstrator with cockpit system integration.

The demonstration logic includes:

- Manufacturing trials of scaled component:
  - Tooling design and manufacturing
  - Inspections & repairs
- Extended ground testing with respect to Clean Sky:
  - Damage tolerance:
    - Damage growth evaluation
    - Repairs feasibility and qualification
  - Vibration (damping)
  - Acoustic
  - Dynamic impact
  - EMC and Electric design validation
- Avionics systems functionality verification.
- Substantiation of structural and systems requirements & interfaces.
- Bird strike strength substantiated by analysis.

### Low Cost Processes & High Efficient Production Technologies

**WP B-3.4 Advanced integration of systems in small a/c**

Advanced system technologies developed in ITD System and focused on reduction of the Operational Costs, improved cabin (noise, thermal, entertainment) & flight comfort and safety and security.

5 key demonstration paths:

- Efficient operation of small aircraft with affordable health monitoring systems.
- More electric/electronic technologies for small aircraft.
- Fly-by-wire architecture for small aircraft.
- Affordable SESAR operation, modern cockpit and avionic solutions for small a/c.
- Comfortable and safe cabin for small aircraft.
### Key Enabling Technologies

<table>
<thead>
<tr>
<th>WP B-3.5 More Affordable Small Aircraft Manufacturing</th>
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<tbody>
<tr>
<td>· automated metal structures assembling</td>
</tr>
<tr>
<td>· Friction Stir Welding technologies for specific structural parts</td>
</tr>
<tr>
<td>· advanced technologies in jigs/fixtures production</td>
</tr>
<tr>
<td>· alternative joining methods</td>
</tr>
<tr>
<td>· effective combination of metallic and composite structures</td>
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<tr>
<td>· advanced production technologies</td>
</tr>
</tbody>
</table>

### Key Demonstration Vehicle

Demonstration activities will be provided on ground demonstrators consisting of central fuselage airframe subassemblies of metal fuselage and wing sections.

Outside of main demonstrators will be built technological demonstrators represented by airframe subassemblies demonstrating advanced production and assembling processes, production hardware innovations (jigs/tools).

Type of test:
- technology verification
- strength test
- fatigue tests

### WP B-3.6 New materials & manufacturing

<table>
<thead>
<tr>
<th>Automation, high speed machining, novel alloys machining, novel forming, bonding, welding techniques, novel part joining techniques, advanced jig technologies, composite parts production techniques, Hybrid metal/composite joining techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced composite materials, noise absorbing materials, multifunction materials</td>
</tr>
<tr>
<td>Production control, testing in production, maintenance in production</td>
</tr>
<tr>
<td>Virtual factory, Manufacturing process optimisation</td>
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</tbody>
</table>

Material testing & validation

Local demonstrations on representative part to validate a production/assembly technique
### V. Links & Interfaces

<table>
<thead>
<tr>
<th>Clean Sky Background</th>
<th>Inner ITD linkage (input/outputs)</th>
<th>Inputs from</th>
<th>Outputs to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eco-Design</td>
<td>Exchanges with the wing structural developments &amp; manufacturing processes Exchanges in the component design &amp; validation cycle. Exchanges in the Eco-Design manufacturing processes synergetic transverse activities</td>
<td>Configuration and requirements from overall aircraft design &amp; configuration management Systems –ITD to account for next generation cockpit functions/equipments and features for the novel cockpit structures Systems –ITD to account for next generation of electrical equipments and power supply</td>
<td>Technology &amp; integration data to synthesis in overall aircraft design &amp; configuration management. Technology validation on component for composite fuselage to the R-IADP Manufacturing processes for all IADPs Further refinement of performance data &amp; environmental footprint from Eco-Design analysis &amp; assessment to Technology Evaluator</td>
</tr>
<tr>
<td>FP7 L2 composite projects ALCAS, SARISTU, LOCHOMACS</td>
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<tr>
<td>FP7 L2 projects such as WELAIR, The SAT related FP7 project: CESAR &amp; SAT Roadmap</td>
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*Clean Sky 2 Joint Technology Initiative in Aeronautics*
VI. High-level Plan

Aircraft OEM will perform the global trade-offs, set the requirements and manage the integration of the demonstrators. They will ensure definition, development & testing of the demonstrators thanks to their key expertise in aircraft fuselage structures and integration process.

Core partners will bring contributions for part design & manufacturing of advanced composite & metallic parts, including assembly and junction techniques (joins ...), lightening protection, surface protection, new efficient production, manufacturing, assembly, maintaining and recycling techniques, new processes, new materials (new aluminium alloys manufacturer, advanced composites, multifunction materials), health monitoring, control (NDC...) tools, techniques and ground (static & dynamic) testing. Support is also expected from providers of High Automated Devices for manufacturing and assembly. Equipments/Sub-systems providers will fit their innovative component in the structure when appropriate for integration demonstration purposes and provide support in integration and more electrical aircraft technologies.

Research Institutes, SMEs and other enterprises will provide a strong support with their excellent track record in simulation & modelling (composite structures, structural optimisation, manufacturing process, advanced coating, lightning, static & dynamic analysis, fatigue ...) and associated relevant advanced testing techniques and means.

VII. Partnerships
9.7.4 Technology Stream B-4: Low Speed A/C Advanced Fuselage

I. Context & High-Level Objectives

In the airframe, the fuselage structure has kept on with old conventional architecture since decades, the main improvement laying on design optimisation and significant progresses in the manufacturing process and substantiation process. From the conventional cylindrical fuselage, the latest innovations in the shape (e.g. A380 ovoidale fuselage) or in structure (composite & advanced aluminium alloys for the A350) were mainly driven by the internal volume expansion optimization, or use of more performing raw material to reduce the weight. Notable progress will be made in Clean Sky, in particular on noise, or structural weight saving for the cockpit & forward fuselage barrel in GRA. But new concepts of fuselage are to be introduced to support the future generation of fast rotorcrafts, and more global aero structural optimizations can lead to further improvements on drag & weight in the context of a growing cost & environmental pressure, including emergence of new competitors.

II. Scope and Added Value versus State-of-the-Art

a. Rotor Less Tail for Fast Rotorcraft - WP B-4.1

The compound helicopter design introduces significant changes to the fuselage requirements, imposing a redesign of the fuselage concept. The development here will focus on the most complex redesign of the fuselage parts: the tail. The objective is to design and manufacture and substantiate a tail assembly matching requirements of the ADP R/C LifeRCraft demonstrator and ensure verification and validation activities for delivery of that component compliant for assembly with the aircraft demonstrator, testing and flight demonstration in the scope of the IADP LifeRCraft Demo Project.

The airframe components will be designed for very light weight and low drag; enabling the full vehicle to reach challenging targets of: empty weight fraction (<63%); equivalent L/D (20% improvement w.r.t. conventional helicopter) with direct impact on speed and payload-range capability.

b. Pressurized Fuselage for Fast Rotorcraft – WP B-4.2

The objective is to validate an innovative fuselage concept that fits the new and challenging requirements laid out by a tilt-rotor process, as a key enabling step of the global in-flight validation of the NextGenCTR demonstrator in the framework of the Fast Rotorcraft IADP.

Work will focus on the architecture definition, design, modelling, analysis, manufacturing and validation of 3 fuselage global components: front, central and rear fuselage assemblies for flight clearance. Deliveries will be architecture description, physical components for testing and for assembly of the technology demonstrator. The fuselage global components will be structurally tested (i.e. static and fatigue) on dedicated benches to support flight clearance whilst individual sub-assembly tests will be performed as required as well.

Global challenges of such an innovative concept will be the weight efficient design of a structure capable of withstandng aircraft-type operating conditions while satisfying helicopter-type operational requirements. Whilst the design objectives of minimal drag and weight, through extensive use of state-of-the-art design simulation tools in the fields of CFD, structural analysis and systems integration, will aim at enabling NextGenCTR CO₂/noise emission reduction targets by reduction of the power required in all phases of flight.
The front portion of the fuselage includes nose, cockpit and front landing gear bay. Specific additional challenges include system integration, operational issues (e.g. good visibility for confined area operations) and ability to accept multiple sensor packages for mission flexibility for example. Careful design and selection of materials will seek to ensure high speed aerodynamic efficiency of the front cross-sectional area of a pressurised fuselage subject to greater high speed loads. Fulfilment of crashworthiness and ditching capabilities at minimum weight and maximum robustness will be sought to be part of the final outcome.

The central portion of the fuselage includes passenger compartment, access doors, wing-to-fuselage interface, baggage compartment and main landing gear bays. Specific additional challenges for the pressurised cabin include high-speed aerodynamic efficiency with low internal noise and resistance to landing loads. The ability to be reconfigured internally for mission flexibility must at the same time also guarantee low MRO costs. Resistance to all types of flight and operational mission requirements for crashworthiness and ditching capabilities will be sought with the best possible maximum all up mass achievable.

The rear component of the fuselage includes the tail portion of the fuselage to aft fuselage tail cone, horizontal and vertical tail surfaces, both fixed and moveable. Specific additional challenges include here the delivery of a capable high-speed aerodynamically effective structure required to withstand and/or provide a variety of longitudinal and lateral control forces for flight in a weight efficient package of limited footprint for operational flexibility in confined areas. The tail cone will also house the Auxiliary Power Unit (APU) and appropriate provisions for it will have to be taken into account. As part of the complete package, this end part of the pressurised fuselage will also seek to minimise any vibratory phenomena and drag or wake effects whilst all crashworthiness and ditching capabilities need to also be guaranteed.

c. More Affordable Composite Fuselage – WP B-4.3

The goal is to develop the advanced composite technology base and integrated structural concepts for fuselage in ways methodology matching the future market pressures of price pressure from new competitor, taking into consideration the future high level of expectations from the eco-compliance. The application case will be based on the performance, cost & environmental objectives of fuselage for a next generation regional aircraft (in accordance with roadmaps to be proposed by the R-IADP Technology Wave WV 6 “Fuselage Technologies”).

Thanks to the demonstration on ground of whole full scale fuselage barrel, an alternative to aluminium alloys for Regional Aircraft Fuselage will be provided, enabling innovative structural solutions for fuselage with increased structural integration, reduced total costs and structural weight and reduced environmental impact, and including extended duration of A/C life.

The composite solutions will include all needed functionalities otherwise to be absolved by opportune add-on increasing costs and weight. Technological investigation will cover:

- new design methodologies for structural sizing, advanced materials, manufacturing and assembling processes minimizing costs, structural weight and environmental impact;
- new maintenance/repair technologies and advanced NDI/SHM techniques.
Taking full benefits of the progress on fuselage structure, the objective is to achieve an improved and optimized passenger cabin environments by the means of an innovative and integrated design approach based on:

- Multidisciplinary human centred Cabin interiors;
- Identification of the comfort key factors in cabin areas and their optimum combination with surrounding cabin systems;
- Environmental friendly cabin materials to improve human interaction with cabin materials in terms of comfort issues;
- Noise and vibration, including active and passive treatments.

The main achievements will be:

- Human centered cabin design: improvement and optimization of main cabin items (seat, panels, lighting system, insulation blanket, monuments) which highly influence the requirements of the human centred design approaches for passenger.
- Virtual design and virtual manikin: large possibilities of cabin parameters variation (colours, lay out, lightening patterns, etc.); manikin adjustable “on demand” (tall, thin, big legs, etc.), prediction of inter-passengers acoustical parameters;
- Acoustics: to take existing single technologies, develop them further and then combine, apply and optimize them on full aircraft level. This last step which includes the multidisciplinary and concurrent optimization of the human-centered N&V treatments in a global A/C model in order to derive an optimal treatment with respect to excitation, human factors and acoustic comfort perception is in effect the new step
- Materials: Integration of bio-based materials; development of chemical-free processes (thermoplastic welding, thermoforming, etc.); - development of VOC (Volatile Organic Compounds) free materials in order to reduce passive toxicity related to the cabin furnitures.

The associated enabling technologies will developed in accordance with roadmaps to be proposed by the R-IADP Technology Wave WV 7 “Cabin Technologies”.

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d. Affordable Low Weight, Human Centred Cabin – WP B-4.4

**Clean Sky 2 Joint Technology Initiative in Aeronautics**
### III. Technologies

#### Key Enabling Technologies

<table>
<thead>
<tr>
<th>WP B-4.1 Rotor-less tail for fast rotorcraft</th>
<th>Key Demonstration Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>• CFD optimization of aerodynamic configuration &amp; design (fuselage tail junction, tail boom, empennage and fins including control surfaces) taking into account constraints for rear access doors and rescue hoist operation, airframe angle of attack and attitude control, dynamic pitch and yaw stability (with and w/o active stability augmentation), interaction with propeller slipstream and tail shake prevention in the full flight envelope including mass and CG variations;</td>
<td>Full scale, flightworthy tail assembly to be delivered for flight demonstrator (shake test and flight campaign);</td>
</tr>
<tr>
<td>• Flow control devices either passive or active to be studied if needed to prevent flow separation;</td>
<td>Full range of calculation and simulation tools (CFD, FEM, dynamics); sample, sub-components and full component ground tests; substantiation documents for Permit-to-Fly.</td>
</tr>
<tr>
<td>• Aeroelastic tailoring to prevent resonance or coupling of tail deformation with rotating components;</td>
<td>The tail assembly includes: tail boom, empennage and fins with pitch and yaw control surfaces.</td>
</tr>
<tr>
<td>• Advanced structural design i.e. topologic optimization using smart combination of composite and metallic materials for minimal weight;</td>
<td>TRL 5 with Airframe ITD; TRL6 after flight demonstration in IADP R/C LifeRCraft project.</td>
</tr>
<tr>
<td>• Green materials, low energy &amp; low scrap production processes, reparability &amp; recyclability</td>
<td></td>
</tr>
<tr>
<td>• Design to Cost (NC, DMC).</td>
<td></td>
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<table>
<thead>
<tr>
<th>WP B-4.2 Pressurized fuselage for fast rotorcraft</th>
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<tbody>
<tr>
<td>The technical objectives will be pursued by means of an optimal design, through extensive use of design and simulation tools such as CFD, structural and vibrational analysis, aeroelastic modelling and systems integration. The detailed design will leverage a dedicated selection of materials and manufacturing technologies (including but not limited to hybrid composite-metallic structures, automated tape laying for single piece outer skin, lightweight hybrid transparencies for de-icing and bird strike resistance, use of thermoplastic matrix composites from initial conception).</td>
<td>Manufacturing of physical components for testing and for assembly of the technology demonstrator with flight clearance related to each of the 3 components: front, central &amp; rear fuselage parts.</td>
</tr>
<tr>
<td></td>
<td>The fuselage will be structurally tested on dedicated benches to support flight clearance. Individual sub-assembly tests will be performed as required.</td>
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<tr>
<th>WP B-4.3 More Affordable composite fuselage</th>
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<tbody>
<tr>
<td>• Methodologies for modelling &amp; simulation for high efficient, high performance computing non linear structural analysis and damage models applied to composite &amp; laminates.</td>
<td>The validation approach is based on a two fold demonstration approach:</td>
</tr>
<tr>
<td>• Affordable technologies to reduce the environmental impact with use of a recycling process based on simple chemical-physical procedures not involving any chemical reactions and needing of low energy consumption.</td>
<td>1. In the framework of the AIRFRAME ITD, demonstrations are carried out up to component level by following the building block approach. Such will include a full scale barrel ground demonstrator.</td>
</tr>
<tr>
<td>• hybrid &amp; composite materials with a high impact resistance or multifunctional composite for acoustic improvements, thermal protection, EME or lightning features or integrated SHM/NDI systems.</td>
<td>2. The generated technology base will be integrated in the full scale fuselage demonstrator inserted in the R-IADP demonstration.</td>
</tr>
<tr>
<td>• technologies for low cost manufacturing with large one piece manufacturing, high</td>
<td></td>
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2014 *Clean Sky 2* Joint Technical Programme (V4) – Proprietary Information subject to Confidentiality Agreements
### Key Enabling Technologies

- automation, advanced infusion, curing & bonding techniques, and low cost assembling with high automation, lean, low infrastructure processes, efficient fastening.
- Impact damage survey on full scale items.
- NDI/SHM techniques for materials, assembling and design, including self-sensing.
- Technologies for complex shapes and high-loaded parts.

### Key Demonstration Vehicle

A small-scale validation activity will be used, specifically targeted at a local change, to define the new concept(s) and validate in a local context according to type of application. Performance, operability and the acceptability of operational aspects will be the primary concerns.

Virtual Reality setups will also be used to support the design conditions, allowing an optimisation of the environment for these tasks and is already used for multiple design processes.

Small scale test will be performed for preliminary validation to assess the comfort index.

Small scale test will be also performed for preliminary validation to assess the noise/acoustic and FST performances of new materials and lining compound solutions.

### WP B-4.4 Affordable low weight, human centred cabin

- innovative multifunctional materials for interiors components including secondary structure integration concepts;
- development of chemical-free processes (thermoplastic welding, thermoforming, etc.);
- development of VOC (Volatile Organic Compounds) free materials in order to reduce passive toxicity related to the cabin furnitures.
- human perception and psychoacoustics with respect to A/C interior noise and vibration;
- new simulation technologies and methodologies for comfort (ergonomics, noise, thermal verification)

### IV. Links & Interfaces

#### Clean Sky Background

- Eco-Design FP7 L2 composite projects ALCAS, SARISTU, LOCHOMACS
- FP7 L2 projects such as WELAIR,

<table>
<thead>
<tr>
<th>Inner ITD linkage (input/outputs)</th>
<th>Inputs from</th>
<th>Outputs to</th>
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<tbody>
<tr>
<td>Exchanges with the wing structural developments &amp; manufacturing processes With Innovative aircraft architecture Exchanges in the component design &amp; validation cycle. Exchanges in the Eco-Design &amp; manufacturing processes synergetic transverse activities</td>
<td>Configuration and requirements from overall aircraft design &amp; configuration management Eco-Design transverse activity</td>
<td>Technology &amp; integration data to synthesis in overall aircraft design &amp; configuration management. LifeRCraft IADP: tail demonstrator for assembly with the rotorcraft demonstrator – substantiation documents for Permit-to-Fly NextGenCTR fuselage components for assembly with the rotorcraft demonstrator – substantiation documents for Permit-to-Fly Technology validation on component for composite fuselage to the R-IADP Further refinement of performance data &amp; environmental footprint from Eco-Design analysis &amp; assessment to Technology Evaluator</td>
</tr>
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V. **High-level Plan**

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<tbody>
<tr>
<td><strong>Advanced Fuselage</strong></td>
<td>Feasibility development, manufacturing validation &amp; substantiation</td>
<td>Feasibility development, manufacturing validation &amp; substantiation</td>
<td>Validation &amp; substantiation</td>
<td>Large full-scale demonstrators, support to IADPs</td>
<td>Validation &amp; substantiation</td>
<td>Validation &amp; substantiation</td>
<td>Validation &amp; substantiation</td>
<td>Validation &amp; substantiation</td>
<td>Validation &amp; substantiation</td>
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<tr>
<td><strong>TRL 3/4</strong></td>
<td><strong>TRL 4</strong></td>
<td><strong>TRL 5</strong></td>
<td><strong>TRL 6</strong></td>
<td><strong>TRL 7</strong></td>
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**General notes:**
1) TRL are expressed with respect to the integration at the AIRFRAME level.
2) TRL are given with respect to the main demonstration stream. Within an activity line, you can have inserted some complementary/additional technology developments that will not achieve the same TRL target.

VI. **Partnerships**

Aircraft OEM will perform the global trade-offs, set the requirements and manage the integration of the demonstrators. They will ensure definition, development & testing of the demonstrators based on their background on aircraft fuselage structures.

Institutes in aerodynamic, in structural analysis, aero-structure: joins, assembly techniques, large test infrastructure (Wind Tunnel), equipment suppliers (SVS, anemometry, antennas)

Core partners will bring contributions for part design & manufacturing of advanced composite & metallic parts, including assembly and junction techniques (joins ...), lightening protection, surface protection, new eco-friendly production, manufacturing, assembly, maintaining and recycling techniques, new processes, new materials (new aluminium alloys manufacturer, advanced composites, multifunction materials), health monitoring, control (NDC...) tools, techniques and ground (static & dynamic) testing. Support is also expected from providers of High Automated Devices for manufacturing and assembly. Equipments/Sub-systems providers will fit their innovative component in the structure when appropriate for integration demonstration purposes. Specific focus will apply on Synthetic Vision System for low visibility techniques, novel anemometry, and advanced sensor integration techniques (antennas, radar, communications...).

Core partners will also support the development for innovation of Cabin interiors and bring contributions for cabin furniture, component & equipment design & manufacturing and acoustics. Complementary supporting actions are related to Virtual design and virtual manikin & the availability of environmental friendly materials.

Research Institutes, SMEs and other enterprises will provide a strong support with their excellent track record in simulation & modelling (manufacturing process, advanced coating, lightning, static & dynamic analysis, fatigue ...) and associated relevant advanced testing techniques and means. They will provide a strong support on dedicated topics such as psycho-acoustics or dedicated noise and vibration activities.
9.8 Work Breakdown Structure

The work will be organized in 9 Technology Streams as presented on Figure 9.1 (High level WBS of Airframe ITD (Level 1)) in section 9.4.1 above:

1. Innovative Aircraft Architecture
2. Advanced Laminarity
3. High Speed Airframe
4. Novel Control
5. Novel Travel Experience
6. Next Generation optimized wing box
7. Optimized high lift configurations
8. Advanced Integrated Structures
9. Advanced Fuselage

Technology Streams decomposed into a total of 32 main work-packages complemented by 9 Management WPs to ensure the management of the Interfaces & Cross-Interactions between WPs, ITDs, IADPs and the Eco-Design TA. The level 2 WBS is presented on Figure 9.2- (Airframe ITD structure (Level 2 WBS)) in section 9.4.3 above.
10 Engines ITD

10.1 Going Beyond Clean Sky

In 2007 the European engine industry leaders committed to build and test five engine ground demonstrators covering all the civil market. The goals were to validate to TRL 6 a 15% reduction in CO₂ compared to 2000 baseline, a 60% reduction in NOₓ and a 6dB noise reduction. This is roughly 75% of the ACARE objectives. Following the worst economic downturn in living memory and the consequent changes to market assumptions (for example the original EIS for the A30x of 2016 has been postponed to no earlier than 2025 following the launch of the A320 NEO) SAGE has adjusted its content to ensure these goals remain achievable. Apart from the consequent delay to the open rotor program which means that TRL6 is not possible by 2016, the bulk of SAGE objectives remain on track. An open rotor ground demonstrator will run and confirm the CO₂ objective, a lean burn combustion ground demonstrator will run to confirm the NOₓ objective and a GTF will run to confirm the CO₂ improvements and noise advantage of such a configuration. An advanced turbo-shaft engine has already run to ensure the environmental goals extend across the whole market while SAGE 3 has run for the first time to validate the cost and weight advantages of an advanced dressings configuration. Events have shown that the original plans for the open rotor from both Airbus and the engine manufacturers were too ambitious and require further work to confirm both the advantages and credibility of this novel concept. Clean Sky 2 will build on these achievements and demonstrate further technologies for the full range of civil aeroengine applications.

Considering each of the markets addressed by the SAGE projects:

The Sustainable and Green Engine ITD in Clean Sky addresses technologies for a wide range of applications including rotorcraft, regional, short range and long range aircraft. The ITD is organised in six projects, each focussed on technologies for a specific market sector.

Projects SAGE1 and SAGE2 address the development and demonstration of open rotor engine technologies for short range aircraft, the two projects taking alternative approaches to satisfying the system requirements and exploring different technological solutions. The projects have delivered comprehensive rig data on uninstalled and, in collaboration with the Smart Fixed Wing Aircraft ITD, installed efficiency and noise behaviour of open rotor systems. The objective in Clean Sky is to achieve a full scale ground-based engine demonstration and Clean Sky 2 will build on this to deliver TRL6 for the installed open rotor propulsion system through an open rotor flight demonstration.

Projects SAGE3 and SAGE6 address the demonstration of engine technologies for long range aircraft with the focus on low pressure systems (fan and LP turbine), lightweight fan containment system, engine controls, external harnesses and pipework and lean burn combustion. These technologies will be demonstrated to TRL6 for high bypass ratio engines in Clean Sky but engine requirements continue to evolve as bypass ratios increase and fan speeds are reduced to address both CO₂ and noise emissions. Clean Sky 2 will develop and demonstrate the technologies to meet these future requirements for large engines.

Project SAGE4 addresses the demonstration of technologies for geared turbofan engines, focussing on applications for regional and short range aircraft. The change from direct to geared drive impacts on the duty of sub-systems throughout the engine, requiring a differently balanced engine cycle and applying new constraints to the engine packaging and design. Technologies to address these changed requirements are being developed and demonstrated in Clean Sky for modules throughout the engine, including the power gearbox, and Clean Sky 2 will
enable further technology insertion and optimisation to reduce the weight and improve the efficiency of the system.

**Project SAGES** addresses the development and demonstration of technologies to reduce CO$_2$, NO$_x$ and noise emissions from turboshaft engines for rotorcraft. Technologies have been demonstrated throughout the engine in *Clean Sky*, reflecting the strong system interactions and highly optimised packaging of smaller engines. These technologies will be further developed in *Clean Sky 2* and their application extended to a turboprop engine demonstrator for the business and regional aviation turboprop aircraft market, thus bringing technologies for emissions reduction to an application that is not directly served by the *Clean Sky* projects.

In addition to continuing technology developments for the regional, short range and long range aircraft markets, the Engines ITD of *Clean Sky 2* will be expanded to address the needs of smaller aircraft and general aviation through an additional work package specifically for a small engine demonstrator.
10.2 Challenges to be tackled for Engine ITD in the Horizon 2020 period

The environmental challenge is always severe for the Engines sector of the industry as the engines are the only part of the aeronautic system to actually consume fuel and so have the most direct influence over CO$_2$, NO$_X$ and noise emissions. The Engine projects in Clean Sky are contributing significant progress towards achievement of the ACARE 2020 goals but the challenge for future aircraft is even greater as the industry focusses on delivery of the even more stringent goals of Flightpath 2050.

Further development and maturation of the technologies already demonstrated in Clean Sky will achieve further benefits but these will be incremental and unlikely to deliver the substantial reductions in emissions required to meet Clean Sky 2 targets. The proposed Engine sector projects therefore face substantial technical challenges to deliver the environmental targets. This is reflected in the nature of the projects, which propose step changes from current state of the art and will deliver substantial improvements in engine technology.

The challenges will be addressed by taking the following actions:

- Development of system level technologies that are a step change from current state of the art engine architectures and capable of delivering substantial reductions in emissions. These system level technologies will be supported by numerous sub-system technology developments, each of which will deliver individual improvements in component efficiencies but also contribute to the overall system delivery.

- An incremental approach to TRL progression, utilising design studies and rig tests to explore and understand the technologies under development, their system interactions and the risks associated with their implementation. The ultimate goal of the project is to achieve TRL6 and a gated approach will be taken to ensure that this is achieved.

- The full capabilities of the European engine sector will be utilised to deliver the programme, with leadership being provided by Rolls-Royce, Safran and MTU but participation in the programme being extended to encompass both large tier 1 suppliers and more specialist companies and research organisations. Opportunities to participate will be offered through the partnering structure of Clean Sky 2 and it is expected that advances in technology will be performed by Core Partners and Partners. The construction of integrated collaborative partnerships to manage these relationships and coordinate the efforts of the industry will be key to meeting the challenges to be faced.
10.3 The Role of the Engine ITD

The European engine sector currently has about 40% of the global market and H2020 will allow it to at least maintain that share. In assessing the economic impact of new engines on new products expected to enter service exploiting H2020 technologies, it is assumed that the current market sector coverage will be maintained. Based on engines worth a minimum of 20% of the value of the aircraft (including engines), the total economic impact of the engines ITD will be €145b based on analysis done by Rolls-Royce in support of the EC impact assessment.

Environment added value wrt H2020:
- Among Clean Sky 2 programme all the Engine ITD demonstrators and technologies (WP1 to WP6) are the most important contributors to the CO\textsubscript{2} emission reduction aimed in H2020. Their benefit ranges between 20% and 25% vs baseline 2000 and respect to the applications.
- Almost all NO\textsubscript{x} reduction actions needed to meet ACARE target are coming from engine improvements.
- Most important contributions to meet ACARE noise target are provided by demonstrator WP 2, WP4, WP 5. For the demonstrator WP1 which provides the most important CO\textsubscript{2} reduction, the noise goal is to reach same level as passenger aircraft entering in service in 2015 equipped with ducted engines (i.e. A320 neo / B737 max.)

Competitiveness added value wrt H2020:
- WP1, WP4, WP5 will maintain and strengthen European competitiveness in short/medium range market by means of major evolutions (WP4, WP5) or potential game changer (WP1).
- WP6 will ensure that Europe retains a fully competitive large engine capability.
- WP3 will allow entering the growing market share in turboprops (all current Regional Aircraft have non European power plant.)

Societal and industry added value wrt H2020:
- All these programmes will continue to enable challenging career development opportunities for European engineers.
- It is expected Engine ITD will provide a focus for the European supply chain to develop their own capabilities and enhance their competitiveness globally.

The basic objective of the Engine ITD is to achieve the goals defined in the documents describing the intermediate goals for 2020 and also to make a first step towards the goals for 2035 on the way to Flightpath 2050\textsuperscript{19}. The successful test will provide TRL 5 to 6 Level for the dedicated technologies implemented in the demonstrators.

The overall breakdown of the targets (table below) – see highlighted/targeted area foresees a contribution of the propulsion system of 20% reduction in CO\textsubscript{2} up to 2020 –completing the ACARE goal for engines, and 30% up to 2035.

\textsuperscript{19} Flightpath 2050 – see “Flightpath 2050 – Europe’s vision for aviation” on www.acare4europe.org
### Goals and Key contributions

<table>
<thead>
<tr>
<th></th>
<th>2020 Vision&lt;sup&gt;20&lt;/sup&gt;</th>
<th>2020 SRIA&lt;sup&gt;21&lt;/sup&gt;</th>
<th>2035 SRIA</th>
<th>2050 SRIA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall</strong></td>
<td>-50%</td>
<td>-43%</td>
<td>-60%</td>
<td>-75%</td>
</tr>
<tr>
<td>Airframe energy need (Efficiency)</td>
<td>-25%</td>
<td>-20%</td>
<td>-30%</td>
<td>-68%</td>
</tr>
<tr>
<td>Propulsion &amp; Power energy need (Efficiency)</td>
<td>-20%</td>
<td>-20%</td>
<td>-30%</td>
<td></td>
</tr>
<tr>
<td>ATM and Infrastructure</td>
<td>-12%</td>
<td>-7%</td>
<td>-12%</td>
<td>-12%</td>
</tr>
<tr>
<td>NON Infrastructure-related Airlines Ops</td>
<td>-4%</td>
<td>-4%</td>
<td>-7%</td>
<td>-12%</td>
</tr>
</tbody>
</table>

Figure 10.1 - CO₂ reduction targets per passenger kilometre and breakdown

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<sup>20</sup> ACARE 2020 — see “2008 Addendum to the Strategic Research Agenda” on [www.acare4europe.org](http://www.acare4europe.org)

<sup>21</sup> SRIA Vol 1 – Realising Europe’s vision for aviation.
10.4 Set up of the Engines ITD

The Engine ITD will be led by Safran, Rolls-Royce and MTU and includes proposals for seven engine demonstrators. The high level Work Breakdown Structure of the ITD shows the demonstrators and leadership of each project.

![Work Breakdown Structure](image)

Figure 10.2 - Work break down structure
Three of the demonstrators will be led by members of the Safran group:

WP1: Open Rotor flight test (Snecma) [budget hosted in LPA IADP]
WP2: Ultra high propulsive efficiency (UHPE) propulsion system technologies demonstrator for Short / Medium Range aircraft [SMR] (Snecma)
WP3: Business aviation / short range regional turboprop demonstrator (Turboméca)

One demonstrator will be led by MTU:

WP4: Advanced Geared Engine Configuration (HPC and LPT technology demonstration).

Rolls-Royce will lead two demonstrators:

WP5: Advanced VHBR technologies for middle of market
WP6: VHBR engine demonstrator for the large engine market

The seventh demonstrator will be led by a core partner to be selected through a Call:

WP7: Engine demonstrator for Small Aircraft Transport
Lower levels of the WBS will be evolved to reflect the requirements of the demonstrators and reflect the contributions of Core Partners and Partners selected to participate in the Engine ITD. It is anticipated that each WBS element will be a self-contained package of work and interfaces between work packages will be identified and managed to ensure system integration.

Core Partners will be chosen through a formal selection process as stated in Clean Sky 2 governing rules. However some of these demonstrators being a further step from Clean Sky achievements and towards a full technology maturation, it is envisaged that existing core partners in Clean Sky SAGE will continue to be among major contributors to this project in order to benefit from their experience acquired in SAGE.

Sharing between Leaders / Core-Partners / Partners through:

Sharing of the Engine ITD total activity between all the partners will comply with Clean Sky 2 governing rules. This will led to an important participation of the core partners and other partners to the actual demonstrators activities (detailed design, hardware building, etc.). The high costs involved in building full engine demonstrators, some of which will be capable of flight testing, are such that it is expected that the contribution to the total costs of the ITD by the Leaders will be more than 40% or, more accurately, that the European engine supply chain (Core Partners, Partners and sub-contractors) will be incapable of contributing 60% of these costs.
10.5  **High level objectives at demonstrator or technology level**

Safran, MTU and Rolls-Royce have secured corporate commitment to build on the success of SAGE to validate more radical engine architectures to a position where their market acceptability is not determined by technology readiness.

10.5.1 **Open Rotor Fligh Test – WP1**

![Clean Sky SAGE 2 Open Rotor demonstrator](image)

*Clean Sky* will deliver ground testing of an open-rotor engine which is one member of a new family of propulsion systems aimed to a strong fuel burn saving. It is believed that these novel architectures, being far from the current experience envelope, will require further studies in terms of concept and technology maturation, benefits evaluation, reduction of concept risks as well as to provide improvements of noise, performance and reliability.

It must be noted that the overall road map for the future propulsion system of short / medium range aircraft will be subject to a number of reviews.

In this WP1 Snecma (Safran) will lead engine related activities required to perform ground test and flight test on the Airbus A340 flying platform of a 2\textsuperscript{nd} version of a Geared Open Rotor demonstrator carrying on *Clean Sky* SAGE 2 achievements:

- Studies and design of engine and control system update and modifications for final flight test
- Manufacturing, procurement and engine assembly for ground test checking before flight
- Following on flight test planned in LPA IADP and test results analysis.

**Technical objectives are:**

- Up to 30 % of CO\textsubscript{2} emission reduction vs. 2000 aircraft, i.e. clearly more than the ACARE 2020 target assigned to Engine. This goal is 17 % better than the assumed 2014 Reference status.
- Noise levels no over those of turbofan which will enter in service in ~ 2015 to power the A320 NEO aircraft (~ -3 to -4 EPNdB per operation vs. year 2000)

**Competitiveness objectives are:**

Maintain and strengthen short / medium range market share by means of a potential game changer.
10.5.2 UHPE Demonstrator for SMR aircraft – WP2

For Short / Medium range passenger aircraft there is a need to open additional technology concept maturation avenues in order to fully explore the benefits and risks of Ultra High By-pass Ratio propulsion system. This includes consideration of the following:

- Advanced low pressure ratio fan / short air inlet / variable area fan nozzle specific technologies adapted to Ultra High Bypass Ratio engine
- Low weight structures; low drag / low noise ducts and nacelle
- Improved module technologies such as power gear box, low pressure turbine, high speed compressor booster, etc.
- Impact on the engine of innovative engine / airframe integration if the case occurs
- Optimization according to aircraft mission and size

Thus, Snecma (Safran) will lead the design, development and ground tests of a propulsion system demonstrator to validate the low pressure modules and nacelle technology bricks necessary to enable an Ultra High By-pass Ratio engine.

Baseline configuration for the demonstrator is made of new low pressure modules and nacelle parts integrated around an existing or adapted HP core in order to form the required ground demonstrator with a bypass ratio anticipated within the range 15-20. Impacts of innovative engine/airframe integration concepts chosen to improve propulsive efficiency could be taken in account.

The activity described in this program is a research activity which, by nature, entails uncertainty and risk as to the benefits ultimately derived. In particular, should at any point a review decide to discard an architecture previously seen as promising because of a clearly proved show stopper, the proposed road map would be reconfigured to reflect a new commonly agreed logic retaining however the same total resource commitment for WP1 + WP2 and ultimate goal which is to identify, mature, optimize and eventually validate the Ultra High Propulsive Efficiency (UHPE) engines and propulsion system concepts for the next generation of short / medium range aircrafts.
Clean Sky 2 Joint Technology Initiative in Aeronautics

<table>
<thead>
<tr>
<th>Technical objectives are, for short / medium aircrafts applications:</th>
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<tbody>
<tr>
<td>▪ Up to 23% of CO₂ emission reduction vs. 2000 aircraft, i.e. at least ACARE 2020 target assigned to Engine. This goal is 9 % better than the assumed 2014 Reference status.</td>
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<tr>
<td>▪ Noise levels making a significant step towards to ACARE 2035 targets ( - 11 EPNdB per operation relative to 2000 situation: including engine, nacelle, aircraft technologies - airframe noise reduction, novel aircraft configurations – and ATM benefits)</td>
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<tr>
<td>▪ Contribute to achieve NOₓ emission ACARE 2020 target ( - 80% vs 2000 baseline)</td>
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**Competitiveness objectives are:**
Retain European competitiveness to maintain European employment levels in a market that will grow faster outside Europe and strengthen short / medium range market share.
10.5.3 Business Aviation/Short Range Regional Turboprop Demonstrator – WP3

Turbomeca (Safran) will lead the design, development and ground testing of a new turboprop engine demonstrator in the 1800-2000 shp class for business aviation and short range regional application. Turbomeca proposes to design, develop and test a global propulsive system built around an adapted very modern existing turboshaft core engine called ARDIDEN3. The demonstration will address two technologic challenges:

- The baseline core of ARDIDEN3 will be improved (combustion chamber for higher altitude operation, specific turbine and propulsive exhaust, specific control system) to better fit with the turboprop application.
- It will then be integrated with an innovative gear box, air inlet, propeller control system and propeller to be designed and developed specifically and ground tested.

Existing ARDIDEN3 for Helicopter Application to be modified and improved for TURPOPROP application

The small size is an important challenge for this kind of high performance propulsive system. This new turboprop will demonstrate a significant improvement compared to the state of the art. It is anticipated that the design and integration of each subsystem to provide an Integrated Propulsive System will lead to better performance for the mission.

Synergy with both SAT and Fast Rotorcraft IADP can be found on comprehensive understanding of subsystems components (such as propeller, air intake for instance). Moreover the ARDIDEN3 has been initially developed for Rotorcraft Application. WP03 can therefore address questions issued from Fast RC IADP and support their activity; in particular, engine models, extrapolated to requested power range, can be provided.

This demonstrator is meant to address both the single medium (SM) and twin medium (TM) turboprop market where engine power ranges from 1000SHP to 2000SHP. Typical aircraft applications are up to 19PAX.

As far as TCO is concerned, the main target is to reach a TBO of 5000 hours on the parts newly developed during the frame of this project. Besides the IPPS will be studied and designed taking into accounts constraints to facilitate the access to the engines & equipments in the nacelle during maintenance operations.

Technical objectives are:
- A strong increase of thermal efficiency equivalent to 20% CO$_2$ emission reduction vs. 2000 baseline. Versus current reference in service, the benefit is 12%
- An additional 8% CO$_2$ emission reduction is foreseen by improving the engine integration and each sub-system design
- Contribute to noise reduction when integrated in a turboprop or turboshaft new product

Competitiveness objectives are:
- Retain European leadership in engines for conventional or breakthrough rotorcrafts
- Enable market share growth in 1800-2000 shp class turboprop engines, currently dominated by North American manufacturers.

### 10.5.4 Advanced Geared Engine Configuration – WP4

During the timeframe of Clean Sky 2 programme some important decisions with a long lasting impact on the aircraft and engine market are expected to be made. For a necessary selection process of the most suitable engine configuration as a technology demonstrator for CS2 the aspect of a timely exploitation has to be taken into account. Both basic types of engine could be of relevance either the next generation of Geared Turbofan as well as a turboprop application could be feasible. However wrt the key objectives of MTU technology strategy for the HP compressor and the high speed LP-turbine, the design requirements and the dominant technology streams are quite similar. So the technologies for both types of engines can be tested in a representative environment. Very preliminary concept studies performed in the frame of CS2 preparation have indicated that already.

MTU has selected a smaller turboshaft engine as a platform for the development of hot section technologies. This platform offers the possibility and the flexibility to extend the key technology enablers from aerodynamic, materials and structures also to design features including variable flow characteristics in hot section components. In the ACARE SRIA this list of technologies are identified as the powerful and most probable means to reduce CO2 emission. On compressor side a compression system rig will be built, in which the planned compressor technologies - in particular relevant for interactions between low pressure, high pressure and static structure - can be tested and achieve TRL6.

Since the technologies developed within the CS2 demonstrator can be transferred to geared turbofan application, the demonstrated improvements can be bookkept also for a geared turbofan. These data can be used as input data for the IADP LPA equivalent to the processes foreseen in the TE.

MTU Aero Engines will lead the design, development and ground testing of a new demonstrator to validate the key enablers to reduce emissions in CO₂ and noise as well as engine weight. The technologies, envisaged to be implemented in the demonstrator, will address the improvement of the thermodynamic cycle efficiency and noise reduction. The key elements are:

- Improvement of aerodynamic efficiency
- Reduction of parasitic energy flows (e.g. cooling and sealing air)
- Weight reduction by using innovative lightweight and temperature resistant materials
- Lightweight structures by optimised design and advanced manufacturing processes
- Noise reduction in LPT and exhaust system.

In particular the availability of innovative high temperature low density materials and adapted structural design will be one of the key points of Clean Sky 2 technologies to reduce weight and to save cooling air.

It has to be stated, that even the configuration of the engine demonstrator will include a power gear box module, this will not be a module for technology insertion in the WP4 demonstrator. The main reason for that is that the main (power) gear box of current technology level in a geared turbofan
achieved a remarkable efficiency level already which can be improved only marginal. So the focus will be put on technologies which have a much higher impact on CO2 reduction, as in compressors and turbines.

On one hand side the environmental objective of CO2 emission reduction is directly linked to fuel burn reduction of the engine. On the other hand fuel burn is one of the main drivers of direct operating cost which, as a third aspect, is an important driver for competitiveness of the product. Combined with weight reduction as a further technology objective of the demonstrator these are one of the strongest contributors for competitiveness. Consequently WP4 is attacking both main objectives namely improving competitiveness of European engine industry and the environmental aspect.

### Technical objectives are:
- Up to 25% of CO₂ emission reduction vs. 2000 reference, which would exceed the ACARE 2020 target assigned to the engine. This corresponds to a further reduction of up to 5% relative to Clean Sky 1 SAGE4 targets to be demonstrated.
- Contribute to ACARE 2020 targets in noise levels.
- A reduction in NOₓ goes along with the CO₂ reduction at comparable combustor technology level.

### Competitiveness objectives are:
To maintain the market position of European engine manufacturer and to maintain the capability for the development of world leading components for competitive engines. Furthermore the proposal is targeting for strengthening European supply base for engine industry.
10.5.5 VHBR Middle of Market Turbofan Technology – WP5

The trend to very high Bypass Ratio engines requires technology development across a broad range of complex gas turbine systems, from fan inlet through the complete compression, combustion and turbine to exhaust. In particular research and demonstration of underlying capability is required in the following key areas:

- Behaviour of fans at low speeds and fan pressure ratios, including fan stall margin and the effect of variable cold nozzle geometries on the fan operability.
- Intermediate pressure compression system due to changes in air inlet conditions and pressure ratio requirements
- Aerodynamic and structural design of multi-stage Intermediate Pressure turbines, considering the structural effects of higher speeds and maximising turbine efficiency within a compact structure.
- Systems integration of novel accessory and power gearboxes, including oil system and bearing technologies.
- Integration of engine and nacelle structures to support the power gearbox and maximise the overall efficiency of the powerplant structure.
- Associated control & electrical power system technology developments integrating the control of all system components.

Rolls-Royce will lead the development and demonstration of technologies in each area to deliver validated powerplant systems matured for implementation in full engine systems. Participation in the project is expected from Core Partners and Partners, who will develop many of the required sub-systems and contribute significant expertise and capability in their specialist areas.

While much research is generically applicable to a range of engines, the project is intended to focus on engines for middle of market single aisle commercial aircraft. Detailed configuration will be guided by whole engine system studies trading the benefits of developments in individual engine modules to develop a specification and requirements set for an optimised whole engine system. This work will itself be guided by early results of the research and a number of iterations in the system design are expected before a final configuration is achieved. Gates in the project planning will manage these decisions and ensure that all project participants are recognised as stakeholders and able to participate in the project development.
Technical objectives are:

- 5% fuel burn and CO₂ emission reduction capability relative to equivalent direct drive engines.
- Noise levels making a significant step towards ACARE 2035 targets (-11 EPNdB per operation relative to 2000 situation: including engine, nacelle, aircraft technologies -airframe noise reduction, novel aircraft configurations – and ATM benefits)
- Contribute to delivery of NOₓ emission reductions through reduced fuel burn. Specific objectives will not be defined owing to the strong dependency on overall core engine cycle decisions.

Competitiveness objectives are:

Maintain European competitiveness in the integration and development of engines for short range commercial aircraft and to ensure capability across the full range of technologies required by geared engines.
10.5.6 VHBR Large Turboprop Demonstrator – WP6

Very High Bypass Ratio (VHBR) Turbofan engine technology has been developed and demonstrated for a first generation of engines for the short range commercial aircraft market and this project will extend that capability to large engines of substantially higher power suitable for long range wide-body aircraft. Building on experience for short range aircraft, the project will demonstrate:

- An integrated low pressure system for a high power very high bypass ratio engine.
- A low speed fan system with blades optimised to low pressure ratio duty and operating in a nacelle with variable area nozzle for operability control.
- Compressor delivering high overall pressure ratio to the combustor from intake conditions provided by the low speed fan.
- Controls systems integrating control of the core engine with control of the variable nozzle geometry to optimise the overall engine cycle.

Rolls-Royce will lead the design, development, build and test of an engine to demonstrate these technologies at a scale suitable for large engines. Whole engine design studies will define the detailed engine configuration, drawing on technology developments and demonstrations in WPS to improve understanding of sub-system behaviours and allow system optimisation. Dependency on underlying technology development precludes an early engine definition but also allows the demonstrator to respond to changing requirements and for the benefits of each technology to be maximised within the overall system. The new core, which is crucial to the performance of the VHBR, will be demonstrated as part of the programme. The engine development plan will require ground and flight testing and it is envisaged that three engines will be built to satisfy these dual needs, with a period of ground testing building confidence in the technology prior to flight.
Technical objectives are:

- 23% fuel burn and CO₂ emission reduction relative to year 2000 baseline (consistent with 10% reduction relative to year 2014 baseline)
- Noise levels making a significant step towards to ACARE 2035 targets (-11 EPNdB per operation relative to 2000 situation: including engine, nacelle, aircraft technologies - airframe noise reduction, novel aircraft configurations – and ATM benefits)
- Specific objectives will not be defined owing to the strong dependency on overall core engine cycle decisions.

Competitiveness objectives are:

Develop a world-leading European capability for Very High Bypass Ratio engines for the large aircraft market, establishing a lead in this emerging market.
10.5.7 Small Aircraft Engine Demonstrator – WP7

The European Small aircraft industry has a market position on the global general aviation and utility aircraft market, both pistons and turboprops (excluding business jets and new category of Light Sport Aircraft), of around 33% in value (total market 2002-2011 around $20Bn) thanks to the technical excellence resulting from past private investments covering all the segments like single/twin engines pistons and turboprops.

Activities in Clean Sky 2 represent research and technology interest in two areas: small gas turbines and lightweight diesel engine.

The gas turbine technology has established the dominance in the aircraft propulsion application due to high power to weight ratio and reliability but its relatively high cost becomes very relevant when the power level decreases up to the small aircraft application (< 1000Kw). Advanced technology in gas turbine of the recent years has concentrated on large engine with a big impact on improving aviation transport efficiency and greening but only a little effort has been made on small gas turbine. The small gas turbine engine is distinguished from large power engine not so much in terms of overall requirements (reliability, relative lower specific fuel consumption etc.) but rather in the severity of problems associated to achieve these requirements in small dimensions of various engine components. As results, compromise must be made on design architecture, materials selection, manufacturing processes, which are suitable to the particular needs of small turbine engine with reduced overall cost. It is clear that without improvement in small engine components design and material and manufacturing this high level target cannot be obtained.

The application of modern lightweight diesel engines in aircraft operations brings the important benefit of better fuel efficiency. The widespread presence of diesel fuel over the world is also important especially in the regions where small aircraft are used. The lightweight optimized for aircraft diesel engine more oriented towards a professional use is the step forward of the current diesel engines. The platform of fuel efficient diesel engines (up to 400HP) will bring the ecological benefit as well as the better reliability and cost efficient service conditions. The engine integration in a single engine aircraft is easier than on a twin engine aircraft due to the large room in the aircraft nose. For a twin engine aircraft, the diesel engine installation penalties are extra drag and weight compared with the other engine installations (both legacy reciprocating piston engines and turbines).

Both topics are established in the Chapter 14 “Small Aircraft Transport (SAT)”, namely in 14.4.2 ITD Engines. Goals of Clean Sky 2 are supporting by WP 0.2 in 14.4 Description of SAT Participation, as a transversal coordination activity within the SAT group and other ITD, coordinates research and application of technologies in all areas of aircraft design.
10.6 Synthesis of Engines ITD Added Value of the demonstrator & technologies vs. state of the art

10.6.1 Open Rotor Flight Test – WP1

Main added value of WP1 is the maturation in representative flight conditions of Geared Open Rotor specific new technologies. It is a natural further step following on the Clean Sky SAGE 2 first ground test planned in 2015. None of the following technologies under the scope of Clean Sky 2 are presently in service or at TRL over 4:

- New composite open rotor blades concepts optimized for aerodynamic and acoustic performances
- Pitch control full system for counter rotating blades (controller, actuators, mechanics,)
- Counter rotating structures (struts, frames, barrels, rings) supporting the blades
- High power gear box with counter rotating outputs in engine rear zone
- High efficiency power turbine integrated in an open rotor engine
- Engine integration and installation in rear fuselage area and solving all the issues about dynamic behaviour, thermal acceptability, cabin noise, certification, etc.

10.6.2 UHPE demonstrator for SMR aircraft – WP2

Main added value of WP2 are validation at scale 1 size and on engine ground running conditions of several technologies not yet tested, or which tests are only planned at reduced scale without mechanical representativeness (e.g. ENOVAL FP7 programme).

This is particularly true for the propulsive front block including fan, nacelle, variable area fan nozzle and power gear box.

To achieve promised high performances it will be mandatory to:

- Demonstrate aerodynamic efficiency and noise performance of the short air intake / low speed fan / exhaust ducts / variable area fan nozzle, considered as a whole, higher than those of today VHBR engines. Operability and impact resistance are also crucial challenges.
- Demonstrate the beneficial impact of an affordable variable area fan nozzle on fan design, operability and noise
- Validate designs of low weight fan, low weight structure and low weight / low drag nacelle modules to not jeopardize UHBR expected benefits on specific fuel consumption.
- Demonstrate highly efficient and robust power gearbox integrated in an actual thermal and dynamic engine environment, and also integrated with the thermal management system (heat exchanger, etc)
- Demonstrate high efficiency and low weight high speed low pressure turbine integrated in engine environment, including high pressure turbine interaction effects. It is considered to select advanced materials (high temperature inter-metallic or ceramic matrix composite) for some blades or vanes.
- Demonstrate high efficiency and low weight high speed booster integrated in engine environment, including fan hub interaction effect.
10.6.3 Business Aviation/short range regional Turboprop Demonstration - WP3

Main added value to present state of art is to bring small size HP cores (1800-2000 shp) for turboprop and turboshaft applications at thermal and pressure levels close of today larger core used for turbofans and also to integrate around this core advanced propulsive modules needed by future turboprops (power gearbox, propeller, nacelle components, etc.). Main progresses versus state of art are:

- HP compressor techniques allowing higher pressure ratio unusual on that power range; the technical challenge is to achieve this higher pressure ratio with an attenuated efficiency losses linked to small size.
- Combustor techniques which can provide NO\textsubscript{X} emission reduction and acceptable operability despite of low combustor dimensions, and able to be integrated in preferred architecture for small size cores.
- Aerothermal integration of the HP turbine and LP turbine redesign together with the exhaust system for better overall performance.
- The integration of the air inlet, compliant with latest anti icing, noise and performance requirements. A modern gear box design, with its lubrication system and a state of the art propeller (performance, noise).
- An advanced propeller control system, with latest actuator technology.
- The design of each subsystem taken each other input to achieve a fully Integrated Power Plant System.

10.6.4 Advanced Geared Engine Configuration – WP4

The Clean Sky 2 demonstrator is the consequent step for 2025+ technology evaluation. Clean Sky (1) SAGE 4 is going to demonstrate up to 20% in CO\textsubscript{2} reduction, which is the biggest step towards ACARE 2020 goals. Above that Clean Sky 2 WP4 is supposed to demonstrate further 5 % reduction in CO\textsubscript{2}.

Furthermore due to budget constraints the level 2 programmes in FP7 (e.g. ENOVAL) are identifying technologies at lower TRL levels. It is part of the overall validation strategy of CS2 WP4 that technologies identified in level 2 programmes running upfront Clean Sky 2 (e.g. ENOVAL 2015-2017) will flow into the Clean Sky 2 engine demonstrator and will be tested in a representative environment to achieve TRL6.

It has to be mentioned that for the introduction of breakthrough technologies in particular the enablers of new materials and manufacturing processes a comprehensive test programme consisting of tests on parts and module rig level are necessary to secure a successful engine demonstrator test.
10.6.5 VHBR Middle of Market Turbofan Technology – WP5

Main added value to present state of art is to develop the full range of technologies required for turbofan engines for Middle of the market applications and demonstrate a generic capability for application in Middle of Market and large engines. Main advances versus state of art are:

- Power gearbox system integration capability developed and demonstrated under a range of operating conditions including long periods of operation at high powers and attitude conditions challenging to the oil system capability.
- Low speed fan system capability development to lower tip speeds and fan pressure ratios than current systems and demonstration through rig testing of blade integrity, performance and operability.
- Multi Stage Intermediate Pressure turbine investigations and design studies into the specifics of VHBR geared-engine applications, capability to be validated by rig demonstration.
- Nacelle and engine structures research to increase structural integration and demonstrate capability for variable nacelle geometries and effect on engine operability.
- Integrated propulsion & electrical power systems with intelligent controls

10.6.6 VHBR Large Turbofan Demonstrator – WP6

Main added value to present state of art is to demonstrate LP system technologies for larger engines, confirming capability of a Very High Bypass turbofan at high powers and validating the environmental benefits of the configuration. Whole engine system studies in the early stages of the project will define the demonstrator detailed configuration but the principal advances beyond current state of the art are:

- VHBR fan drive system capability for high power engines within aerospace constraints of space and weight, integrated with a full engine system and demonstrated under a range of operating conditions.
- Low speed fan system capability extended to very large diameter engines of high power and demonstrated in respect of aerodynamic performance, structural behaviour and impact resistance.
- Multi-stage Intermediate Pressure turbine capability demonstrated in an integrated full engine system for high power operations.
- Variable area nozzle technology impact on the operability of low speed fans demonstrated in a full engine system environment, including flight conditions.
- Demonstration of a new core technology which will underpin the VHBR large Turbofan Engine.
10.6.7 Small Aircraft Engine Demonstrator – WP7

Engine Activities in Clean Sky 2 dedicated fully to SAT [small air transport] will focus on research and technology interests in two areas: light weight diesel engine and piston/hybrid engine architectures. For the WP7 related demonstration, the main progresses versus the state of the art will be:

 Improvement of the aviation transport efficiency and greening for small aero-engines.
 Finding a compromise on design architecture, materials selection, manufacturing processes suitable to the particular needs of small turbine engine with reduced overall cost.
 Important benefit in terms of better fuel efficiency will be made through the application of modern light weight diesel engines in aircraft operations. The platform of fuel efficient diesel engines (up to 400HP) will bring the ecological benefit as well as the better reliability and cost efficient service conditions.
10.7 High-level plan with schedule, major milestones, deliverables, TRL to target

Below text and tables provide for each WP the first level of WBS, the schedule, main milestones (Mx) and main deliverables (Dx).

10.7.1 Open Rotor Flight Test – WP1

WP1 Open Rotor Flight Test demo is aimed to procure TRL 6 beginning of 2021 for the Geared Open Rotor Architecture thanks a flight test on an Airbus A340 flight test bed in the Large Passenger Aircraft IADP.

It is foreseen Core Partners and Partners involvements would be on the same components or modules as for Clean Sky SAGE 2: rotating frames, power gear box, power turbine and pitch control mechanism. Those components are concerned by WP 1.2, WP 1.3 and WP 1.4.

Important remark: It must be noted this work plan and its deliverables shall be performed by means of the major part of the Safran budget contained in the LPA IADP proposal (see also paragraph 8).
Clean Sky 2 Joint Technology Initiative in Aeronautics

a. **WP 1.1: Propulsion System Integration**

This WP deals with the integration of modified (from Clean Sky ground demo) and possibly new components. An important part is the mechanical and thermal integration for flight (installation, loads, dynamics, all thermal managements and related heat exchangers). The other important part is the aero-performance evaluation and status, including nacelle aero-design. It is considered a low speed wind tunnel model test representing the flying blades geometry and their interaction with the pylon wake could be performed in this WP. Whole engine models (digital mock-up, contribution to platform finite elements model, etc) will be updated. Interfaces documents for the propulsion system and its integration into the platform will be established. Finally failures and hazards analysis and related risk abatement plan will be also necessary.

Concerning the link between Clean Sky SAGE 2 and present Open Rotor Flight Test program, it is shown in below schedule that designs for flight test will be frozen (CDR) only 2 years after SAGE 2 ground test completion and data analysis, and PDR is planned 1 year after SAGE 2 test completion and data analysis. So, SAGE 2 management structure and team will have the capacity to insure the transition between the two programs, and final definition can take in account all pertinent technical information coming from engine behavior during ground test and from test data.

Informations that would appear needed by “Eco Design 2” would be prepared in the present WP.

b. **WP 1.2: Modules Adaptation or Modifications**

The modules to be adapted for flight test will be more precisely determined in 2014-2015. After airworthiness analysis and taking into account several previous tests (models and ground demo) it will be decided what non flight-able parts from propeller module of the Clean Sky ground demo will have to be re-designed and manufactured. It can be noted that airworthiness analysis and then preliminary design of some parts to be modified according conclusions can be started before analysis of SAGE 2 ground test data. It is foreseen some nacelle components will be new and manufactured (air intake with de-icing and foreign objects protection functions, part of gas generator dressing, engine mounts systems, etc). These components must receive instrumentation consistent with safety and demonstration requirements.

The main tasks of this WP consist in preliminary design, detailed design and then manufacturing of the Open Rotor Propulsor components or parts as well as Nacelle components or parts which have to be adapted or modified.
c. **WP 1.3: Systems and Controls Development**

Some systems components will be re-designed and manufactured or procured to be flight-able or adapted to the flying platform (accessories gearbox, starter, some oil system modules, heat exchangers, etc). Control System will be developed to be consistent with flight test requirements (control laws adjustments, engine protection, fire protection, etc). These components must also receive instrumentation consistent with flight test requirements. The control system will be validated on system ground rig, in dry and wet configurations.

The main tasks of this WP consist in preliminary design, detailed design and then manufacturing of the modules or components of the Systems and Controls selected after the above studies for modification or adaptation.

d. **WP 1.4: Components Maturation Plan**

It is planned to check ability of critical components to be used on the flying test bed thanks to some partial test like endurance test for power gearbox, over-speed tests of selected rotating parts coming from the propeller module, staircase tests, fatigue tests for engine mounts and other critical components. These tests will be ran and completed before engine delivery.

e. **WP 1.5: Preparation and Participation to Demo Flight Tests**

This WP starts with Clean Sky ground demo dismantle and inspection, followed by instrumentation and assembly of flight tests built. Then the open air test bench will be adapted to receive the flight test built and an engine ground test before flight will be performed mainly for operability, performance assessment and “pass-off test”. Snecma will support Airbus to install the propulsion system on the flight test bed and will participate to flight test follow-on. The final step will be flight test data analysis and demo engine inspection.

The main objectives of this flight test are to check the Open Rotor behavior in actual flying condition and installed in a rear fuselage area. For engine domain the scope is: dynamic and mechanical behavior, operability and transients over the whole flight profile (pitch control,...), vibrations, noise characteristics at aircraft scale with installation effects, etc.

This WP includes also building and providing engine data to LPA IADP leader in charge of integrating overall performances at aircraft level to be used by “TE2”.
### WP1 / Snecma: Open Rotor Flight Test

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10.7.2 **UHPE Demonstrator for SMR aircraft – WP2**

WP2 is aimed to procure TRL 5-6 maturation mid 2021 for a set of specific technologies dedicated to Ultra High Propulsive Efficiency concept. Chosen architecture is an Ultra High Bypass Ratio turbofan (ducted architecture) having a bypass ratio preliminary anticipated within the range 15-20. The purpose of this WP is to:

- demonstrate and validate the overall performances (Specific Fuel Consumption,...) of the UHBR concept by assessing mainly the parts brought by the low pressure components measured in actual engine environment
- obtain some characteristics of the new modules as well as their mechanical and dynamic behavior in actual engine environment
- obtain acoustic data from engine ground test to consolidate noise benefits at aircraft level

It is considered Core Partners and Partners participations to some fixed structures contained in WP2.2, participation to components in WP2.4, participations to some components in WP2.5 and participations to rotor shafts and bearings.

WBS 2nd Level of « UHPE Demonstrator »
a. **WP 2.1: Candidate, Concept, Demo Architecture, Demo Integration**

In this WP several UHBR turbofans architectures for high propulsive efficiency concepts (engine + nacelle + systems) will be drafted and their overall interest evaluated using preliminary studies tools (specific fuel consumption, noise emissions, drags and weight). A preferred candidate for Short / Medium Range aeronautic transport will be selected and preliminary designed.

Then a demonstrator architecture using an existing (or slightly adapted) High Pressure Core will be drawn in order to be able to demonstrate the viability and the performances of the critical low pressure modules and of some critical nacelle components or systems. High Pressure Core selection will be done at the end of the first working year.

This WP contains also the integration tasks of the demonstrator (coordination, specifications, interfaces, dynamic/structural/thermal overall demonstrator behavior, performances evaluation, etc) using or providing inputs from / to the following WPs.

Informations that would appear needed by “EcoDesign 2” would be prepared in the present WP This WP includes also building and providing engine data to LPA IADP leader in charge of integrating overall performances at aircraft level to be used by “TE2”.

b. **WP 2.2: Propulsive System (Fan, Compressor Booster, Cold Structures, Nacelle, Nozzles)**

The propulsive front block contains the main challenge of the UHBR in terms of efficiency, noise, weight, drags and noise of their various components. The strong interactions of these components must be taken into account in their designs. This work package will start with following components study and design tasks:

- Short air intake in strong aero / acoustic interaction with the fan at several operating points
- High efficiency low pressure ratio fan having low weight / low blade count characteristics thanks to advanced 3D woven composite and updated physics simulation tools.
- Outlet guide vanes / fan casing / mid structural frame and exhaust duct optimized as a whole to minimize aero distortion, weight and dimensions. Use of 3D composite for some fixed structure will be decided during the studies.
- Air intake and exhaust ducts will receive advanced acoustic liners adapted to low frequency UHBR fan source
- There is a high probability that the fan operability and aero / acoustic optimization will require a variable area fan nozzle (VAFN), combined or not with a thrust reverse function.
- The high speed booster module will be also designed with challenging objectives in terms of efficiency, weight and dimensions and using advanced aerodynamic controls techniques (e.g. casing treatment, etc.)

The main tasks of engineering teams in this WP consist in preliminary designs followed by detailed designs of the modules from the above list. It must be noted most of this modules have specific characteristics coming from UHBR thermodynamic cycle or architecture, going outside of the conventional turbofans parameters domain and then asking for deeper investigations, optimizations and sometimes for new basic technologies as listed above.

All the above modules will be manufactured in order to be assembled around the selected HP core and to form the ground demonstrator. Concerning nacelle parts it is anticipated the demonstrator could receive bell mouth or representative air intake, VAFN and core nozzle, but not the cowls full package.
It is considered Core-Partners and Partners participations to some fixed structures contained in this WP.

c. **WP 2.3: Transmission System**

For the considered by-pass ratio (over 15), and the related low pressure ratio / low tip speed fan, a power gear box is needed to disconnect the low pressure turbine (LPT) speed and the fan rotational speed and avoid long and heavy LPT. This gear box will be designed and manufactured in the present WP as well as the fan shaft and LPT shaft. Specific design providing low power loss level / high reliability / low weight will be investigated. Power gear box efficiency has a major impact on oil heat exchanger size and then associated fan duct pressure loss which is a critical parameter for UHBR turbofans. The selection of the specific gearbox architecture and technology implemented in the demonstrator will be done during the first two years according the below schedule.

The integration tasks of the gear box within the structure of the propulsive front block will be also performed in the present WP under close links with WP 2.2 and WP 2.1. Partial test (attitude and/or limited endurance test) of the power gear box is a possibility that will be considered. However gearbox behavior embedded in engine environment is considered as the most useful test. So, power gearbox partial test would be considered if risk mitigation to secure engine demonstrator running appears necessary.

All the transmission system components devoted to the ground demonstrator will be manufactured in this WP.

d. **WP 2.4: Low Pressure Turbine (LPT)**

The high speed low pressure turbine will be designed and manufactured in this WP. The design task must be performed under iterations with WP 2.1 in order to optimize the overall propulsive efficiency (specific fuel consumption + drags). Fan, exhausts and LPT flow paths need to be optimized in a coupled procedure.

Advanced 3D blades and vanes aero designs, including new concepts, will be introduced in the LPT module. It is also considered to use advanced light weight materials well adapted to the LPT blades and vanes temperature range.

Advanced sealing and cooling or thermal management devices could be considered and introduced or not according benefits and maturity.

All the LPT components will be manufactured in order to be assembled with the selected HP core and to form the ground demonstrator.

Same remarks as for the WP 2.2 is made for the present WP, that is to say the main tasks of engineering teams in this WP consist in preliminary designs followed by detailed designs. The specificity of this LP turbine will ask for deeper investigations, optimizations and sometimes for new basic technologies implementation as listed above.

It is considered Core Partners and Partners participations to some components of this WP.
e. **WP 2.5: Controls & Other Systems**

Due to higher thermal fluxes to be managed and necessity to avoid prohibitive nacelle cross section increase, UHBR architecture needs specific and non conventional fuel, oil and electronic systems with most of their components installed around the HP core. In the demonstrator core and nacelle compartments must represent as close as possible the challenge of the final product. Accessory gear box, oil system and thermal management, including heat exchangers and their integration are the major challenges. However, fuel system and electronic control unit of the demonstrator may be partially re-used from the engine donor of the existing HP core or taken from test bench equipments.

The variable area fan nozzle mentioned in WP 2.2 needs an accurate, light and reliable actuation and control system. For the demonstrator those systems will be limited to the demonstration purpose. In parallel, it is considered an actuation system concept better representative of the product, possibly including electrical actuators, and which test is foreseen on “Copper Bird” bench within ITD Systems program and budget.

It is considered Core Partners and Partners participations to some components of this WP.

f. **WP 2.6: Demo Built Up and Ground Tests**

Components instrumentation and overall instrumentation required to check performances and mechanical behavior versus the demonstrator objectives will be defined and implemented in the hardware (sensors for steady and transient measurements of gas and structure parameters). The full demonstrator will be assembled from all modules and components provided by above WP, including the existing (or slightly adapted) High Pressure core. The demo will be then installed in a ground test bench. Performances tests will be performed as well as measurements allowing acoustic signature assessment. Mechanical and dynamic behavior will also be characterized. Finally test data will be analyzed and the assessment of the UHPE concept overall performances will be done.

Update of engine data provided to LPA IADP leader in charge of integrating overall performances at aircraft level to be used by “TE2” will be done in the present WP.
### WP2 / Snecma: UHPE demo for SMR aircraft

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**TRL Progress**

- **3**: Concept selection
- **4**: Demo specifications
- **5**: PDR
- **6**: Engine & bench ready for ground test
- **7**: Report on Ground Test
- **8**: Demo 1st Run
10.7.3 Business Aviation/Short Range Regional Turboprop Demonstrator – WP3

WP3 targets the acquisition of technologies for a high performance turboprop in the 1800-2000 shp class which will significantly upgrade the actual product efficiency. This demonstrator will deliver technologies maturity up to TRL 5/6 in 2019 with capability to be part of next generation of aircrafts.

The purpose is to provide an alternative to US products with an optimized solution based on a whole Integrated Power Plant System; each Subsystem will be optimized taken into account the other subsystems and the overall target.

The current reference is has 83% of market share in the considered power class. The Ardiden 3 core engine adaptation is targeted to offer 12% savings in fuel consumption and its optimized integration (within the IPPS) will aim at bringing 8% in addition, compared to the latest engine versions.

The purpose is to bring to the market a new generation of TP; each subsystem of the TP is meant to become the new state-of-the-art to achieve a global improved solution.
a. **WP 3.1: Whole Integration of the Propulsion System**

This WP deals firstly with engine specification, intended to be performed in collaboration with an airframer as partner, and it also includes interaction with Technical Evaluator. Then whole propulsion system integration study activity will define each TP component specification and interfaces (structural, performance, system, safety).

This work package covers the specification and evaluation of the integrated power plant system. The activity will first consist in elaborating the specification of the Integrated Power Plant System (IPPS), based on which the IPPS architecture will be selected. The specifications of each subsystem (interfaces, system requirements) will then be derived and provided to the other work packages.

An airframer will collaborate to support the activities of specification and to assess the performance of the IPPS. Part of its task will also consist in interacting with the Technical Evaluator.

This work package covers also the ground tests of the IPPS (core engine + gear box + Nacelle + Propeller + Systems) at Turbomeca facility. The possibility to perform an aircraft integration testing (ground or flight to be defined) may also be considered.

b. **WP 3.2: Core Engine adaptation for TP Usage**

It is foreseen the ARIDEN 3 core engine components adaptation will concern the combustor (partial test will be considered), the HP turbine (advanced materials) and the power turbine and exhaust system specifically designed for the TP engine. Core engine integration will also require adaptation of the systems (secondary air system, fuel and oil system, etc). Core engine test will be performed in ground test cell under conditions to be determined.

c. **WP 3.3: Gear Box module**
Power gear box (PGB) and accessory gear box (AGB) will be designed and manufactured. A specific test cell will be designed and built in order to validate the behavior of the PGB+AGB in propeller static and dynamic loads environment. It is anticipated that core partners will participate to this WP.

d. **WP 3.4: Propeller**

This work package is dedicated to propeller advanced design. This activity will include investigations for reduced propeller noise. In particular, the noise reduction will be a key driver for the design of the propeller.

After design methods update needed to obtain high aerodynamic and acoustic performances, the propeller, its actuation system and the propeller control system including the over speed protection will be designed. Components needed by the final TP test will be manufactured. It is anticipated that core partners will participate to this WP.

e. **WP 3.5: Air Inlet and Nacelle**

The air intake, its de-icing system, and the particle separator will be designed using updated methods (aero, thermal, trajectories, etc.) in order to obtain a competitive concept. All the nacelle parts and nacelle systems will be designed, manufactured and provided to WP 3.1 for full TP test. It is anticipated core partners will participate to this WP.

f. **WP 3.6: Turboprop innovative accessories**

Innovative solutions are welcome for several accessories required by the demonstration like oil system (centralized functions), bleed system, starter/lighting technology, sensors, etc. Accessories required by the demonstration will be designed and manufactured. It is anticipated partners will participate to this WP.
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**Clean Sky 2 Joint Technology Initiative in Aeronautics**

**WP5/ Turbomeca:**

- **Business Aviation / SR regional TP demo**
- **Preliminary discussions with RA and RC IADP (Impact of integration on engine technologies)**
- **Specification of integrated technologies**
- **Preliminary studies and choice of demo concept**
- **Specifications of partner tasks and deliverables**
- **Preliminary design**
- **Detailed Design**
- **Manufacturing**
- **Demo instrumentation, assembly**
- **Ground test core engine**
- **Ground test full propulsive system**
- **Results analysis**

**TRI Progress:**

- **M1: Full functions specification**
- **D1: Demo specifications**
- **M2: Engine cycle**
- **D2: Partner task specifications**
- **M3: PDR**
- **M4: COC**
- **D3: PPA available**
- **D4: Core engine ready for tests**
- **M5: Core engine 1st run**
- **M6: Full propulsive system 1st run**
- **D6: Report on Ground Test**
10.7.4  Advanced Geared Engine Configuration – WP4

WP4’s technology programme is aimed for testing key enabling technologies as advanced materials including manufacturing processes in rig and engine demonstrator to prove the necessary technology level up to TRL6. In MTU’s demonstrator the main activities are focused on technologies for HPC and LPT including adjacent components impacting the design and performance of the focused modules. In the WBS as shown in the picture below only the modular tasks are mentioned, as the main work packages. Additionally, there are non modular system related work packages. The main scope of the non modular task is to perform concept studies and to ensure that the modules are specified such that all modules are consistently fitting into the whole engine demonstrator concept.

The level 1 work break down structure is split into the modules in which technologies will be implemented. The areas for which the contribution of Partners or Core-Partners is foreseen are mentioned explicitly.

The WP4 is structured into the main sub-tasks illustrated in the picture below and described as follows:
a. **WP4.1. Compressor Intermediate Casing IMC**

The intermediate casing is the functional link between the LP and the HP compressor. The aerodesign of the IMC flowpath is impacting the flowpattern of the HPC aerodynamic inlet plane and therefore part of the overall integrated aero optimization of the HPC. Furthermore it is providing the structural function of the casing which results in a contribution to the tip clearance in the HP compressor. The IMC also integrates the bearing support structure and the bearing casing itself. Optionally this would offer the possibility to implement new bearing technologies in the intermediate casing. This work package consists in the structural design according a system requirements document as well as in the aerodynamic optimization for minimum pressure losses, optimized flow profiles and distortion levels at the HPC aerodynamic inlet plane. For weight reduction purpose newest material and manufacturing technologies will be applied. It is foreseen to integrate core partners in this work package. This module will be tested in a rig environment and potentially in the engine demonstrator.

b. **WP4.2 HP Compressor**

The HP compressor will be designed to introduce technologies of the next generation contributing to the overall objectives of H2020. The intention is to validate aggressive aero design at extended design criteria, in order to achieve weight savings at specified aerodynamic target values for aerodynamic efficiency, flow capacity and compressor stability. New design features for improved tip clearances and sealing will be implemented as well. The WP consists in design, manufacturing and test validation of this new compressor.

c. **WP4.3. Turbine intermediate casing**

The intermediate casing is the functional link between the HP and the LP turbine. The aerodesign of the turbine intermediate casing flow path is impacting the flow pattern of the LP turbine aerodynamic inlet plane and therefore part of the overall integrated aero optimization of the LP turbine. Furthermore it is providing the structural function of the casing which results in a contribution to the tip clearance in the LP turbine. The turbine intermediate casing also integrates the bearing support structure and the bearing casing itself. Optionally this would offer the possibility to implement new bearing technologies in the intermediate casing. This work package consists in the structural design according a system requirements document as well as in the aerodynamic optimization for minimum pressure losses and optimized flow profiles at the LP turbine aerodynamic inlet plane. For weight reduction and cooling air reduction purposes advanced and new material and manufacturing technologies will be applied. Lightweight and higher temperature resistant materials incorporated in this component are a key technology item. The module will be tested in an engine demonstrator. It is foreseen to integrate core partners in this work package.

d. **WP4.4. LP Turbine**

As MTU is already working on high speed turbine since years the focus of this work package will be on the continuous improvements in the LPT module with technologies of the next generation. In particular an integrated aero design, new light and temperature resistant materials, designs and manufacturing technologies will contribute to the H2020 objectives. The aero design of the LP turbine will take into account the HP turbine exit conditions and the intermediate flow path at the LP inlet as well as the characteristics of the TEC and exhaust system. For the Turbine as well as for the turbine intermediate and turbine exit casings one of the key technology element is the availability of lightweight and temperature resistant materials to gain overall performance benefits.
and weight reduction. Innovative designs and manufacturing methods have to be adapted. Material and manufacturing technology maturation will be performed jointly with research partners and suppliers.

e. **WP4.5. Turbine Exit Casing and Exhaust System**

In order to optimize the complete LP expansion system the Turbine Exit Casing (TEC) and exhaust system have to be taken into account. The exhaust system can consist in either an annual duct or the shape or a lobe mixer reducing mixing losses downstream of the LP turbine. The configuration of the exhaust system will be selected after a configuration study. The aerodynamic design of the exhaust system partly determines the operating conditions of the LPT and thus the performance and noise emissions. In the exhaust system design features to reduce the noise emissions will be integration and thus contribute to the noise reduction targets. Depending on the configuration of the demonstrator, the TEC can be a structural part providing the support of the rear bearing or a sole flowpath duct. Both components TEC and Exhaust system are supposed to be delivered under the responsibility of partners.

f. **WP4.6. Testing of Rigs and Engine Demonstrator**

Validation by testing under relevant operating conditions is a substantial aspect to bring the incorporated technologies up to TRL 6. It is planned to test on two levels. The first test level are module test rigs running at representative test conditions which will allow to reach TRL levels up to 6. For some technologies the complete validation strategy can foresee rig evidence providing TRL 5 to TRL6. In particular technologies in the hot section will be incorporated in the planned engine demonstration as the second test level. Test hardware and special test enabling hardware are planned to be part of the contribution from partners.
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10.7.5 VHBR Middle of Market Turbofan Technology – WP5

WP5 will demonstrate a range of underlying technologies necessary for very high Bypass Ratio engines in all markets, although focusing on demonstration for the Middle of Market short range aircraft. A series of design studies and rig tests will deliver TRL4-5 for each technology although full system demonstration will take place in other programmes.

The following provides a summary of the next level of work breakdown descriptions.
a. **WP5.1 – Low Fan Speed / Pressure System and Structural Technology**

This work package will investigate the behaviour of fans at low speeds and fan pressure ratios, including fan stall margin and the effect of variable cold nozzle geometries on the fan operability. It is envisaged this work package will include the following elements:

- Concept and Design studies on optimal aero-performance of composite fan systems.
- Investigation into low fan speed behavior and operability
- Composite casing optimisation and integration (of liners, nacelle and externals).
- Light-weight, aero-dynamic front support structure and Outlet Guide Vanes with potential to carry structural loads and optimized for noise.
- Non-structural vanes with anti-ice capability.
- System design studies – optimised design from aero and noise rig results.
- Compressor structures essential to the integrity of the engine.

It is anticipated a Core Partner will participate in this work package with the potential for delivery of hardware into the Rolls-Royce engine demonstrator work package, WP6. Due to the need for delivery of complex, safety critical components with high impact capability and high structural integrity, previous core partner experience in delivering similar components is essential to ensure the project focus remains on TRL development for the VHBR application.

b. **WP5.2 – Multi-stage IPT Design**

This work package will focus on the development and demonstration of various technologies required to deliver a Multi-Stage Intermediate Pressure Turbine module. These technologies are likely to include:

- Aerodynamic Design and Testing
- Aeromechanical Assessment
- Material evaluation and development
- Manufacturing capability
- Methods development
- Noise management technology

The *Aerodynamic Design and Testing* will be based on the material properties developed within Task 3 and the design rules derived from those in Task 2. It will comprise of rotating cascade tests as well as of multi-stage rig tests and will also have to address concepts of over-tip leakage management in this challenging low Reynolds / high Mach number environment.

The *Aeromechanical Testing* will have to focus on the development of design rules for the use of a yet not fully characterised material for the rear stages of the Multi-stage IPT, on new concepts for blade shrouds and blade lifing as well as on the stress assessment and lifing methods for the disc concepts.
The **Material evaluation and development** will include a significant amount of work towards the full characterization of a new LPT Blade material for the rear stages of the IPT as well as the evaluation of existing disc, casing, shroud, vane and blade materials for use in this high speed and temperature environment of an IPT.

The need to develop new **Manufacturing** capability, e.g. Direct Laser Deposition for weight savings in static parts, will be assessed as well.

The advancement of **Methods** is required as well, in particular when it comes to the development of validated tools for forced response and predictions of resulting blade stresses.

Lastly, the aerodynamic concepts for a HS LPT are likely to result in the need for new **Noise Management Technology** in order to arrive at competitive overall engine noise levels. In here, both concept and test work is planned.

The overarching theme of these topics is to arrive at a structural design of multi-stage Intermediate Pressure turbines optimised to high speed operation, considering the structural effects of higher speeds and maximising turbine efficiency within a compact structure and in order to maximize and validate overall performance, structural integrity, reduced weight, cost and noise benefits.

The following share of the work within the WP is expected: It is anticipated that a Core Partner will lead this work package and will work independently on all tasks whilst providing RR with clear visibility and insight into progress made and the results achieved. As such, the Core Partner will therefore be required to have significant and demonstrated previous experience in complex aerodynamic rig test programmes, assessment of entire engine sub-systems and modules in order to be able to derive and develop concepts for the new IPT module, experience with engine module designs for these complex multi stage IPT environments, proven OEM capability to provide the manufacturing capability required as well as demonstrated ability in delivering major packages of work and hardware to time.

c. **WP5.3 – Power Gear Box System Integration**

One fundamental way of achieving a step change in aero engine cycle efficiency is via the development of very high bypass ratio engine architecture. A pivotal component for the delivery of slower fan speed with multi-stage IPT is the power gearbox. While the physical gearbox design will be undertaken outside of the Clean Sky 2 Programme, the complexity of a power gearbox system designed to meet the required power transfer drives the requirement for the development of associated enabling technologies, for example; delivery of large volumes of lubrication oil and management of heat generated, bearing technologies, more electric sensing and actuation, and advanced health monitoring.

It is anticipated that there will be significant opportunities for partner involvement in this work package, with the additional potential for delivery of hardware into the Rolls-Royce engine demonstrator work package, WP6.
**d. WP5.4 – Optimised power plant**

In this work package a number of whole engine and power plant integration studies will be performed and the logistical and future producability challenges shall be investigated.

A key factor in aero-management of power plant is the engine configuration and packaging of external dressings and the integration of the dressings with nacelle structures. Whole power plant structural integration therefore plays an important role that requires investigation. For example, structural support for major sub-system such as the core mounted gearbox and power gearbox will be fundamental to the success in maximising the overall efficiency of the power plant structure.

Other areas of integration work to be conducted will be focused on optimisation of range of systems to be integrated together to form an overall functional system. For example:

- Cold stream system elements, including addressing the challenges of intake compatibility with low pressure ratio fan and assessing the implications and challenges of using variable area nozzles to optimise the fan system.
- Exploring the potential benefits of further full power plant integration including potential structural and/or load path optimisation.

An important element of power plant integration to be factored will be noise, hence design work on LP noise system is planned, especially to investigate the interactions between Fan and VAN.

No power plant can operate without a means of control hence one major element of the work package will be to conduct research in associated control and electrical power system. This will include integration of more electric components/systems. Engine health management technologies will be a consideration in this work content. It is envisaged that there will be significant opportunity for partner involvement in this package.

This work package will also conduct investigations into how to overcome the logistical and build challenges of ensuring that the concepts and designs created for an optimised power plant can be borne into fruition, (or identified means), within the H2020 timeframe. Examples of challenges to be addressed are low cost optimised maintenance solutions in terms of designing for minimal overhaul and shop visit frequencies and durations. Ability to build repeatability to high level of accuracies and volume as well as logistics and special tooling for handling a propulsor architecture will also be a prime consideration.

**e. WP5.5 – Compressor System**

This work package will study aero optimisation of the compressor system to deliver high overall pressure ratios from a low speed inlet condition. The work will build on existing compressor research programmes such as LEMCOTEC.

Areas of interest will be focused on functional behaviour and control for high efficiency and stability. In addition consideration of optimised compressor structures for low tip clearance will be made in this work package. It is envisaged that rig testing of the down selected concept will be conducted.
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10.7.6  VHBR Large Turbofan Demonstrator – WP6

WP6 targets the extension of Very High Bypass Ratio technologies to large engines for the long range airliner market. The demonstrator will validate technologies to TRL6 in 2019 in preparation for the next generation of wide body airliners. Building on the technology validation delivered by WP5, the project will develop these for higher power engines and ultimately demonstrate the technology at full system level in ground and flight test.

Comprehensive system requirements capture and structured validation planning will form the basis for the project, which will adapt to changing technology requirements in the early stages.

The following provides a summary of the next level of work breakdown descriptions:
a. **WP6.1 – Low Pressure System**

One of the fundamental elements to be demonstrated on a full-scale engine demonstrator is the complete integrated low pressure system for a high power, very high bypass ratio engine. The LP system will be heavily influenced by the whole engine architectural decisions but it is probable that the design will be taken and developed from WP5.1, 5.2, 5.4 and 5.5 to deliver a low speed fan system with blades optimised to low pressure ratio duty and, if required, operating in a nacelle with variable area nozzle (VAN) for operability control.

The demonstrator will also verify the Compressor’s ability to deliver high overall pressure ratio to the combustor from intake conditions provided by the low speed fan.

This work package will cover the specific design work conducted for the demonstrator as well as the manufacture of full scale engine hardware. Hence it is anticipated that the Core Partners from WP5 may provide hardware for the engine demonstrator.

Focusing onto the delivery of the Multi-Stage IPT, the major part of the work will have to focus on the implementation of the following:

- From WP5: New materials, e.g. increased temperature disc and blade alloys (high temperature inlet)
- Enhanced active tip clearance control
- Simplified design styles to reduce part numbers for improved reliability and longevity
- Advanced inter-stage sealing
- Noise reduction technology for high-speed LPT (from WP5)
- Integration issues, such as thermal, structural movements, Aero and end load management optimisation, TGT measurement and overspeed protection.
- Optimised aero and structural interfaces with surrounding structures.

As stated in WP5, the Core Partner will therefore be required to have significant and demonstrated previous experience in the assessment of entire engine sub-systems and modules in order to be able to derive and develop concepts for the new IPT module, experience with engine module designs for these complex multi-stage Turbines environments, proven OEM capability to provide the manufacturing capability required as well as demonstrated ability in delivering major packages of work and hardware to time.

b. **WP6.2 – Core Engine**

Rolls-Royce will deliver a full engine demonstration of the High Pressure core, called Advance 3, as part of this Work Package. The Advance 3 core includes a significant change in the work split between the compressors and turbines and introduces a two stage high pressure turbine, compared to the single stage turbine in current Trent engine architectures. This new core is crucial to the performance of the UltraFan engine and is therefore critical to its success.

The activity in the Work Package will take the Advance 3 core (built into a donor Trent XWB engine) and complete the ground test demonstration phase. This would constitute a significant milestone for the UltraFan programme - providing the confidence to take the new core architecture and build the new LP and IP systems.
around it, including the new power gearbox. The core and donor engine would be managed outside of the Clean Sky 2 programme, but the key demonstration testing would be delivered through Work Package 6.

The ground-based demonstrator is a hybrid vehicle which consists of the Advance 3 core, integrated with key elements of both the XWB and Trent 1000 engines. The heavily instrumented demonstrator will provide the ideal platform for demonstrating the functional and system behaviour of the new core architecture, as well as deliver indicative core performance figures, through approximately 300 hours of test programme.

This core will suit the optimised power plant work to be conducted in WP5.4, but the design work to integrate the core engine with the VHBR LP system of WP6.1 for ground and flight testing will also be conducted under this work package.

Another crucial demonstration requirement and significant component of this work package will be to optimise the Control systems, integrating the control of the core engine with the control of the variable nozzle geometry to optimise the overall engine cycle for overall engine efficiency and operability.

c. WP6.3 – Nacelles and Externals

Definition of the Nacelle and external dressings to be demonstrated will be defined once WP5.4 has been completed and initial demonstrator engine designs conducted.

It is anticipated that a full power plant complete with new intake, nacelle, engine with VAN and full suite of externals will be ground and flight tested. As such, investigations in optimal build sequences may be conducted under this work package, either through modelling work or in physical build.

Some of the predicted tests to be performed would be to verify functionality of van system, nacelle aero integration, and perform performance and operability mapping exercises.

It is likely that, working with the LPA IADP, a core partner will be required to develop Nacelle technology and provide hardware for demonstration purposes.

d. WP6.4 – Integrate and Manage

This work package will not only manage the programme side of delivering the demonstrator programme but it will also define the test requirements that will create the specific tests to be conducted.

The current intention is to conduct a series of ground tests to build confidence in the whole engine functionality and durability and to then proceed to flight test. Ground testing will provide valuable verification data for the whole engine system and individual technologies as well as data to support flight clearance. Hence definition of instrumentation will become vital and may result in the requirement to develop of new instrumentation acquisition methods.

Due to the novel architecture of the engine demonstrator, it is anticipated that special handling, build tools and test equipment will be required to be developed. Outcomes from WP6.3 will be used to define what tools may be required to develop the testing capability and deliver all supporting equipment for engine build and test.
Though the size of the engine demonstrator is currently unknown, it is likely that the engine may push the current boundaries and experience at Rolls-Royce’s facilities. Hence modifications to some ground test facilities may be required and will be managed through this work package. Additionally, the potential exists to work closely with Airbus in the LPA IADP when defining and executing the flight test. This may be to inform the overall engine design based on constraints of suitable flight test aircraft and to specify and undertake any modifications to the aircraft which may be required as a result.

This work package will provide models and/or data of the large VHBR turbofan as required by the Technology Evaluator program (TE). Four models will be provided over the course over the 5 year period 2015 to the end of 2019; a baseline model for comparative purposes, an initial and updated VHBR engine model at interim stages of the programme, and a final ‘TRL6’ VHBR engine model which can be used to confirm the improvements relative to baseline.

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10.7.7 Small Aircraft Engine Demonstrator – WP7

WP7: Planning and work breakdown to be developed at a later stage (Core-Partner Work Package foreseen).
10.8 Interactions and interfaces with other ITDs / IADP’s/ TE

The interaction with the IADP’s is summarized in Figure 10.3. Data exchanges concerning specifications and programs results will take place between each Engine ITD WP and a specific IADP in order to prepare global data outputs needed by Technology Evaluator program (TE). TE will use only data already integrated at aircraft levels and issued by the adequate IADP as well as data output from the engine ITD where no IADP aircraft model is available (UHBR, TP demonstrator).

Systems ITD could need some engine characteristics and performances to perform their tasks. The data to be provided by each Engine ITD WP to Systems ITD will be defined during the final set up of the Systems ITD and Engine ITD.
11 Systems ITD

11.1 Going Beyond Clean Sky

The Systems for Green Operations ITD in Clean Sky addresses technologies in two main clusters:

**Mission Trajectory and Management (MTM)** addresses the optimisation of all flight phases with from an environmental and operational point of view. Main developments cover:

- “Green trajectories” to optimise flight performance;
- Weather management to avoid adverse conditions and increase crew awareness;
- Electrical Taxiing to reduce environmental costs of ground phases.

**Management of Aircraft Energy** builds from the results of previous projects such as MOET and prepares systems and solutions for more electrical aircraft configurations. Main issues addressed:

- Power generation and conversion, wiring, etc;
- Power management and distribution;
- Power systems: WIPS, ECS, nacelle, generation, conversion and distribution.

At mid-programme, initial results from intermediate TRL gates and assessments show significant contributions to the environmental objectives of Clean Sky:

- Noise reduction in take-off, landing and taxi phases;
- Reduction of fuel consumption and CO₂ emissions in all flight phases;
- Possibility to take in consideration other environmental aspects (contrails, etc.) through multi-criteria flight management functions.
The work identified in Clean Sky will carry on as planned in the Programme with a view to mature technologies and will hopefully confirm the initial assessments.

11.2 Challenges to be tackled for Systems in the Horizon 2020 period

In Clean Sky, the Systems for Green Operations ITD has developed solutions for more efficient aircraft operation and technologies which are essential to elaborate new aircraft architectures, allowing future game-changing from European aeronautics’ sector. Specificities of aeronautics (environment, safety, reliability, etc.) require relevant technology maturation demonstrations before being potentially considered for an actual application. Further maturation and demonstration as well as new developments are needed to accommodate the needs of the next generations of aircraft. In addition, the systemic improvements initiated by SESAR and NextGen will call for new functions and capabilities for environmental or performance objectives, but also for flight optimisation in all conditions, flight safety, crew awareness and efficiency, better maintenance, reduced cost of operations and higher efficiency. Finally, framework improvements will be needed to allow for more efficient, faster and easier-to-certify development and implementation of features and functions.

The Systems ITD in Clean Sky 2 will address these challenges through the following actions:

- Work on specific topics and technologies to design and develop individual equipment and systems and demonstrate them in local test benches and integrated demonstrators (up to TRL 5). The main technological domains to be addressed are cockpit environment and mission management, computing platform and networks, innovative electrical wing systems (WIPS, sensors, and actuators), landing gears and electrical
systems (including E-ECS). Other contributive activities are foreseen and will be carried on by core partners, research centers, etc. The outcome of these developments will be demonstrated systems ready to be customized and integrated in larger settings. An important part of this work will be to identify potential synergies between future aircraft at an early stage to reduce duplication.

- Customization, integration and maturation of these individual systems and equipment in IADPs demonstrators. This will enable full integrated demonstrations in IADPs and assessment of benefits in representative conditions.
- Transverse actions will also be defined to mature processes and technologies with potential impact on all systems, either during development or operational use. Examples of these transverse actions can be development framework and tools, simulation, incremental certification, integrated maintenance, eco-design, etc.

11.3 The Role of the Systems ITD

While systems and equipment account for a small part of the aircraft weight and environmental footprint, they play a central role in aircraft operation, flight optimisation, and air transport safety at different levels:

- Direct contributions to environmental objectives: optimised green trajectories, electrical taxiing, more electrical aircraft approach, and have a direct impact on CO₂ emissions, fuel consumption, perceived noise, air quality, weight gain.
- Enablers for other innovations: for example, bleedless power generation, actuators, innovative power distribution systems are necessary steps for the implementation of innovative engines or new aircraft configurations.
- Enablers for air transport system optimisation: many of the major improvements identified in SESAR, NextGen and Clean Sky for greening, improved mobility or ATS efficiency can only be reached through the development and the integration of on-board systems such as data link, advanced weather systems, trajectory negotiation, and flight management predictive capabilities.
- Smart answers to market demands: systems and equipment have to increase their intrinsic performance to meet new aircraft needs without a corresponding increase in weight and volume: kW/kg, flux/dm3 are key indicators of systems innovation; competitiveness is at stake.

Systems are a necessary enabler of most of the high-levels objectives set by ACARE and FlightPath 2050. They account for a major part of the cost and performance of aircraft. Many systems and equipment’s actors in Europe have a worldwide leadership position and the whole supply chain mobilize numerous stakeholders, especially SMEs.

The Systems ITD team has taken into account results defined priority domains where innovative approaches are needed to meet the challenges of future air transport.
11.4 Setup of the Systems ITD

The high-level Work Breakdown Structure for the Systems ITD reflects the major work areas described in §1.3.

In each 1st level WP, the initial breakdown shows standalone activities that will be performed by a team of leaders, core partners and partners. In most cases, these activities will allow the WP members to support a TRL 3 or TRL 4 gate for the researched topics.

Whenever possible, activities performed in individual Work Packages will be integrated and consolidated in major demonstrators in order to further TRL achievements and assessments. For this reason, there is no point-by-point correspondence between the WBS and the list of major demonstrations detailed in the next sections. Each 1st level WP includes a support & demos WP where TRL 3/4 technologies will be demonstrated, assessed and pre-integrated in order to support a TRL 4/5 gate and prepare customisation for further integration in target IADPs. These support & demos WPs will also prepare supporting activities for demos, such as simulation tools, benches, etc. in order to maximise synergies between Level 2 WPs.

This WBS should evolve at least until – and probably after – the start of the project, in order to reflect:

- Complementary work or new work items proposed by other parties such as other leaders, candidate core partners, SAT initiative members, etc.
- New priorities or topics following intermediate TRL gates and assessments during the early phases of individual developments.
These changes and additional activities will be implemented in the ITD work plan as additional level 2 or level 3 WPs.
## 11.5 List of Systems Demonstrations

The main demonstrations planned for the *Clean Sky 2* Systems ITD are listed in the table below.

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<thead>
<tr>
<th>Activities / Demonstrations</th>
<th>Content / Technologies</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Contributing WP</th>
<th>Key Contributors</th>
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<tr>
<td><strong>Extended Cockpit Demonstrations</strong></td>
<td>Flight Management evolutions: green technologies, SESAR, NextGen, interactive FM Advanced functions: communications, surveillance, systems management, mission management Cockpit Display Systems: new cockpit, HMI, EVO, etc. IMA platform and networks</td>
<td>Green Trajectories. Enabler for SESAR &amp; NextGen SESAR, weight &amp; operational costs reductions Weight reductions</td>
<td>Integrated approach of global ATS Scalable, modular approach to cockpit electronics for reduced ownership costs and easier updates. New possibilities for airlines operations. Reduced Direct Cost of Operations</td>
<td>Flight safety. Operational credits, enabler for smoother &amp; more efficient travel. Reduction of operational costs should benefit passengers.</td>
<td>Two main targets: TRL 5/6 in 2015 for <em>Clean Sky</em> &amp; other projects technologies - TRL 5/6 in 2018 for breakthrough approaches</td>
<td>1.1 1.2 1.3 1.4 1.5</td>
<td>Open to coherent Core-Partner additional activities proposals</td>
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<td><strong>Innovative Electrical Wing</strong></td>
<td>New actuation architectures and concepts for new wing concepts High integration of actuators into wing structure and EWIS constraints Inertial sensors, drive &amp; control electronics Health monitoring, DOP</td>
<td>Enabler for reduced wing drag Weight saving Fuel saving Removal of environmental unfriendly fluids</td>
<td>Reduced aircraft cost of ownership (DOC)</td>
<td>Availability of functionalities increased, new functionalities added. Simplified maintenance</td>
<td>TRL 5 to 6 between 2018 to 2020+ No flight demonstration</td>
<td>3.1[JRC38] 3.2 3.4 5.2.1 6.[JRC39]</td>
<td>Open to coherent Core-Partner additional activities proposals</td>
</tr>
<tr>
<td>Activities / Demonstrations</td>
<td>Content / Technologies</td>
<td>Green objectives</td>
<td>Industrial Leadership</td>
<td>Mobility</td>
<td>Complete by</td>
<td>Contributing WP</td>
<td>Key Contributors</td>
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</tbody>
</table>
| **Smart Integrated Wing Demonstrator** | Innovative electrical actuators, integrated drive and control electronics, WIPS concepts for new wing architectures  
Shared power electronics  
Electrical power management of wing systems | Enabler for More Electrical Aircraft, reduced wing weight and thus Fuel saving, reduction of electrical power consumption | Lean assembly, new concepts for wing integration,  
System optimization and trans-ATA mutualisation helps to A/C optimized architectures |                                                                                 | TRL5: 2020+ | 3.1 3.2 3.3 3.4 100.1 | Open to coherent Core-Partner additional activities proposals |
| **Structure Integrated System Demonstrator** | New actuation architectures and concepts for new wing concepts  
Innovative actuator designs for integration into wing structure  
New sensor concepts and health monitoring functions | Enabler for reduced wing weight and reduced drag, Fuel saving | Lean assembly, enabler for product differentiation  
New concepts to combine structure and systems | Enabler for improved cruise control via multifunctional system | TRL5: 2020+ | 3.1 3.2 3.4 100.2 | Open to coherent Core-Partner additional activities proposals |
| **Advanced Electrothermal Wing Ice Protection Demonstrator** | Optimized design and structural integration, optimization of ice protection technologies and control strategy  
Health Monitoring and maintainability and reparability  
New wing configurations | Fuel burn reduction, enabler for bleed less engine/aircraft architecture  
Power consumption reduction | Integration with other A/C systems (ATA24, 42...) and improved modularity with other electrical consumers |                                                                                 | TRL 5: 2020 | 6.2 100.3 | Open to coherent Core-Partner additional activities proposals |
| Activities / Demonstrations            | Content / Technologies                                                                 | Green objectives                                                                 | Industrial Leadership                                                                 | Mobility                                                                 | Complete by                                                                 | Contributing WP | Key Contributors                                                                 |
|---------------------------------------|----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------|--------------------------------------------------------------------------------|}
<p>| Advanced Landing Systems              | Optimized cooling technologies for brakes Green taxiing EHA / EMA for MLG applications | Weight savings Removal of environmental unfriendly fluids Energy consumption reduction Reduce noise on ground | Competitiveness Reduced aircraft cost of ownership (DOC) | Short Turn Around Time (~15min per rotation) New operative modes on ground | TRL 5 to 6 between 2018 &amp; 2020 | 4.1 [JRC40] 6. [JRC41] 4 | Open to coherent Core-Partner additional activities proposals |
| Electrical Nose Landing Gear System Demonstrators | Full electrical landing gear system for nose gear EHA/EMA technology Electro-Hydraulic Power Packs Health Monitoring | Weight saving and fuel saving. Enabler for More Electrical Aircraft. | Competitiveness in view to hydraulic-less aircraft, Reduced operating cost Life extension through use of health monitoring | New operative modes on ground. | TRL5: 2018 | 4.2 100.2 | Open to coherent Core-Partner additional activities proposals |
| Electrical Rotorcraft Landing Gear System Demonstrator | Full electrical landing gear system for Rotorcraft based on EMA technology. Remote Electronics, shared PE modules Innovative Drive &amp; Control Electronics | Fuel saving by operative mode and weight savings. Avoid environmental unfriendly fluids | Reduced maintenance costs, technological advance. | New operative modes on ground. | TRL5: 2020+ | 4.3 100.1 | Open to coherent Core-Partner additional activities proposals |</p>
<table>
<thead>
<tr>
<th>Activities / Demonstrations</th>
<th>Content / Technologies</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Contributing WP</th>
<th>Key Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Next generation Main and APU standalone electrical power generation</td>
<td>new generation starter generator for future aircraft (AC and DC network) with full digital control and starter box unit, health monitoring</td>
<td>Weight saving Optimized energy Reduction of fuel consumption and CO2 emissions</td>
<td>Platform to evaluate the integration of starter generator machine in engine test bench, GETI platform. LPA, RA IADP and Bizjet application</td>
<td>New operative modes on ground and in flight</td>
<td>TRL6 : 2020</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>Dedicated Electrical Power Generation</td>
<td>Specific starter generator and Motor for emergency flight operation: Integrated motor technologies, with high speed rotation and high temperature material</td>
<td>Weight and Fuel saving</td>
<td>Rotorcraft application</td>
<td>New operative modes on ground and in flight Reliability performance</td>
<td>TRL4/5 : 2020</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>Innovative Electrical Network</td>
<td>Develop &amp; integrate breakthrough components to create a highly decentralized and flexible innovative power Electrical demonstrator.</td>
<td>Optimized energy consumption (-5%) Electrical system weight reduction (-15%) Simplify EWIS installation (-20% in length)</td>
<td>Trans ATA 92/24 innovative architecture, Generic technological brick ➔ enabler for future aircrafts</td>
<td>Aircraft availability and efficiency</td>
<td>TRL 5: 2020</td>
<td>5.2.1</td>
<td>[JRC42]</td>
</tr>
<tr>
<td>Power Management Demonstrator</td>
<td>Electrical Power Centre for Large Aircraft – load management and trans-ATA optimization</td>
<td>Fuel saving</td>
<td>Key driver to reach the expected benefits of electrical aircraft</td>
<td>Aircraft availability (dispatch)</td>
<td>TRL 5: 2020</td>
<td>5.3</td>
<td>6.4</td>
</tr>
</tbody>
</table>

2014 Clean Sky 2 Joint Technical Programme (V4) – Proprietary Information subject to Confidentiality Agreements
<table>
<thead>
<tr>
<th>Activities / Demonstrations</th>
<th>Content / Technologies</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
<th>Mobility</th>
<th>Complete by</th>
<th>Contributing WP</th>
<th>Key Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Management Center</td>
<td>High integrated power center for bizjet aircraft (with multi ATA load management, power conversion, power distribution and motor control)</td>
<td>Weight and Fuel saving</td>
<td>Trans ATA mutualisation</td>
<td>New operative modes on ground and in flight</td>
<td>TRL6 : 2020</td>
<td>5.2 5.3</td>
<td>Open to coherent Core-Partner additional activities proposals</td>
</tr>
<tr>
<td>Conversion AC-DC and DC-DC for Next Electrical Generation Architecture</td>
<td>Integration new generation power electronic components and materials for passive components. Additional functionalities for power converters</td>
<td>Weight saving</td>
<td>Modularity power conversion to A/C optimized aircraft</td>
<td>Maintenance facilities</td>
<td>TRL5 : 2019</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>Next Generation EECS Demonstrator for Large A/C</td>
<td>New generation of EECS including a global trans ATA visionable to answer the needs for load management, Inerting systems, Thermal Management, Air quality &amp; cabin comfort</td>
<td>Fuel saving Avoid environmental unfriendly fluids</td>
<td>System optimization and trans-ATA mutualisation helps to A/C optimized architectures</td>
<td>Improvement of air quality, passenger comfort and safety</td>
<td>TRL4: 2018 TRL 5: 2019 TRL 6: 2020</td>
<td>6.1 6.4</td>
<td></td>
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</table>
### Clean Sky 2 Joint Technology Initiative in Aeronautics

<table>
<thead>
<tr>
<th>Activities / Demonstrations</th>
<th>Content / Technologies</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Next Generation EECS Demonstrator for Regional A/C Thermal Management And Cabin Comfort</td>
<td>Development / optimisation of Regional A/C EECS components for full scale performance demonstration &amp; cabin comfort</td>
<td>Fuel saving. Avoid environmental unfriendly fluids</td>
<td>System optimization and trans-ATA mutualisation helps to A/C optimized architectures</td>
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<td></td>
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<td></td>
<td>Improvement of air quality, passenger comfort and safety</td>
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<td></td>
<td></td>
<td>TRL 5: 2020 TRL 6: 2020+</td>
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<tr>
<td>Next Generation Cooling systems Demonstrators</td>
<td>New generation of cooling systems for additional needs of cooling</td>
<td>Fuel saving. Avoid environmental unfriendly fluids</td>
<td>Bringing innovative solutions for additional needs of cooling</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>Improvement of passenger comfort</td>
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<td></td>
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<td></td>
<td>TRL 5: 2018</td>
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</tbody>
</table>
### Activities / Demonstrations

<table>
<thead>
<tr>
<th>Activities / Demonstrations</th>
<th>Content / Technologies</th>
<th>Green objectives</th>
<th>Industrial Leadership</th>
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<th>Complete by</th>
<th>Contributing WP</th>
<th>Key Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical Motor Demonstrators</strong></td>
<td>Motor for major load: Introduce high speed rotation and high temperature material</td>
<td>Weight and Fuel saving</td>
<td>Multi ATA applications</td>
<td>New operative modes on ground and in flight</td>
<td>TRL4/5</td>
<td>6.5</td>
<td>Open to coherent Core Partner additional activities proposals</td>
</tr>
<tr>
<td></td>
<td>Motor for major load: Motor for dedicated power generation</td>
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</tr>
<tr>
<td></td>
<td>Introduce high speed rotation and high temperature material</td>
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<tr>
<td></td>
<td>Low power motor: New generation electrical motor with optimized materials, high integrated electronic control for future aircraft network</td>
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<tr>
<td><strong>Demonstration Platform – COPPER Bird®</strong></td>
<td>Use to maturate technologies, concepts and architectures developed in Clean Sky 2 or from other R&amp;T programs and integrated in Clean Sky 2. Large demonstration platform</td>
<td>N/A</td>
<td>Essential platform to evaluate new technologies and architectures for future aircrafts</td>
<td>N/A</td>
<td>N/A</td>
<td>5.13 [JRC43</td>
<td>4]</td>
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<td>Activities / Demonstrations</td>
<td>Content / Technologies</td>
<td>Green objectives</td>
<td>Industrial Leadership</td>
<td>Mobility</td>
<td>Complete by</td>
<td>Contributing WP</td>
<td>Key Contributors</td>
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<tr>
<td>Demonstration on GETI Platform</td>
<td>Adaptation and use to maturate technologies developed in <em>Clean Sky 2</em> or from other R&amp;T programs and integrated in <em>Clean Sky 2</em>. Optimization and validation of the thermal and electrical management between the main electrical consumers Integration of most advanced prototypes in relevant test bench</td>
<td>N/A</td>
<td>Integration and cross-ATA optimization of thermal and electrical systems for future aircraft</td>
<td>N/A</td>
<td>Large test platform to reach higher TRL level for electrical equipment / systems (from 4 to 5 depending of the application).</td>
<td>6.4</td>
<td></td>
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<tr>
<td>Small Aircraft Systems (SAT)</td>
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<td>See SAT description</td>
<td>7</td>
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</tbody>
</table>
### 11.6 Activities and demonstrations

**Important Note:**

In this version, Systems ITD activities mostly cover the foreseen work of the initial writers of the section (THALES, LIEBHERR, SAFRAN). While comprehensive, this is still only a part of the final objectives of the ITD in terms of activities and demonstrations. Further versions will be completed with:

- Topics and work items proposed by candidate Core Partners. It is expected that these additional activities will both strengthen the already identified development activities and complete the list of technologies and demonstrations with new items.
- Additional topics or parallel developments to address new segments, such as SAT. Section 11.7.2 identifies some of these additional activities.
- Transverse activities such as TE related work, Eco-Design and other general threads to be coordinated at programme level (simulation, health monitoring, certification, etc.
- Complementary, “blue sky research” topics to prepare step-change innovations that will be necessary to fulfil the high-level objectives set by the EC.
11.6.1 Cockpit, Avionics & Mission Management – WP1

- The need for an integrated approach

Cockpit environments have seen major transformations in the past decades. These changes have been brought by the combination of several trends:
- technological progress (for displays, flight controls, sensors, etc.)
- higher integration into ATC (flight management systems, communications, datalink, etc.)
- evolutions in crew composition and crew workshare (less crew members, better workshare, etc.)

The current cockpits provide an unprecedented level of technology, information and connectivity to the crew, which translates into higher safety, better efficiency, and lower operating costs.

Technological progress will remain a major driver for cockpit evolution, and all cockpit systems will for sure benefit from current research and development in avionics, sensors, data fusion, etc.

In addition, major changes to the whole Air Transport System (SESAR, NEXTGEN, full permanent connectivity, new communication channels and formats) will call for huge changes in cockpit systems and in flight operations. This will result in higher efficiency, higher capacity of the ATS, better crew awareness and enhanced safety.

It is likely that the cumulative effect of these changes will call for new procedures, innovative role-sharing, more integrated mission management. For these evolutions to become reality, extensive work has to be performed:
• on each sub-system (displays, FMS, sensors, functions, communications, etc.)
• but also, and mostly, on the cockpit system as a whole, in order to prepare:
  - the handling of new operation principles and procedures
  - human factors work on new crew roles, workload evaluation
  - degraded modes, certification aspects
  - the evolution of all cockpit components to keep pace with technological progress and new requirements
during the aircraft lifespan.

The high-integration, high-TRL objectives of Clean Sky 2, along with exceptional project duration and outstanding
volume of activity are a unique opportunity to fully prepare the cockpits of future aircraft:

• Continued development of subsystems as described below:
  - displays,
  - functions,
  - flight management systems,
  - platform and networks
  - enablers such as sensors, navigation systems, communication ...

Note: work already engaged in FP7 and national projects will be leveraged and matured in Clean Sky 2 to
produce building blocks up to TRL 5.
• Work on modularity, upgradeability, to prepare for future requirements, system changes, incremental
certification
• Integrated approach with support of major airframers to define and evaluate cockpit layouts, displays, procedures, using a common synergetic approach whenever possible
• Customisation and actual integration in representative aircraft-level platforms in the IADPs to progress on architecture and perform technical and operational assessment of a full flying environment with pilot-in-the-loop evaluation.
• Parallel work on cockpit systems to define future building blocks and possible specificities for aircraft segments.
• Integration of major building blocks in the Systems ITD to evaluate common concepts and need for customisation for IADPs
• Customisation according to IADP specificities
• Integration in IADP platform

This cockpit-level approach will be implemented in a classical “V cycle” work organisation in WP1:
However, the various sets of constraints and requirements, may lead to a parallelization of the above phases, as well as a specific planning for some of the target IADP cockpits, depending on their commonalities. Also, the best environment to perform the final assessment of a target configuration may be either in the Systems ITD or in a target IADP.

Notwithstanding the specific adjustments performed to meet IADPs’ requirements, the main Extended Cockpit demonstration will be finalized and assessed inside the ITD.

- **Interaction and interfaces with other ITDs / IADPs / TE / ECO and within ITD Systems**

  The most important links between the Systems ITD and the IADPs will take place in the “high-V” part of the traditional V-cycle process:

  - **Requirements** : while first-level constraints on the cockpit demonstrators will have to be identified and satisfied in the ITD, there is a higher level of integration and global design that must be addressed in an airframe context: for example, flight commands, a major part of the cockpit environment, are not addressed directly in the ITD, and any impact on cockpit design must be identified at an IADP-level. The same applies to many other systems and functionalities.

  - Conversely, after the assessment of the global extended cockpit and the customisation and evaluation of the ITD deliverables, a higher-level of test and evaluation must be performed in a more representative environment.

  This need for nested loops of specification/development/test has been taken into account both in the IADPs and in the systems ITD. ITD work will be integrated in higher-level demos in the IADPs, as illustrated for example in LPA IADP, WP3.
### 11.6.1.1 Requirements, Architecture – WP1.1

The first activities in Extended Cockpit will focus on the identification of overall constraints and requirements to be accommodated in the future cockpits. These activities will be performed with the support of the IADP leaders, with a view to:

- Define the general characteristics and main targets of the demonstrations (cockpit layout, architecture, HMI philosophy, crew management, main functions and operations to be implemented, …)
- Define the evaluation scenarios and main assessment targets to be used in the demonstration phase(s)
- Define the aircraft level constraints imposed by the airframers: cockpit layout and geometry, cockpit size, interface with new or legacy aircraft systems

These two steps will lead to an identification of common development path and synergies for some cockpit concepts, while some other layouts will be so strongly different in terms of requirements or constraints that their development will branch out from the main Extended Cockpit work, to be handled in a separate development.

For each development branches, customisation & integration documentation will be defined in order to prepare demonstration, assessment and hand-over to IADPs from the start.

Finally, some cockpit developments will not take place inside the Extended Cockpit baseline, either because they are too specific from the start (could be the case for SAT cockpit needs), or because they cover early, lowTRL concepts that will be better addressed in a parallel development and specific demonstration “Other Cockpit Threads”.

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**Operational WPs**

<table>
<thead>
<tr>
<th>Operational WPs</th>
<th>Inputs/Outputs in ITD Systems</th>
<th>Inputs from other ITD/IADP</th>
<th>Output to other ITD/IADP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 1.5</td>
<td>• ↔ WP1 work and building blocks (cockpit, flight management systems, functions) • WP2 work and building blocks PIMA, networks, …</td>
<td>• LPA, RA, FRA: requirements and airframer-level constraints. Preliminary guidelines for needed customization. • Contribution to final assessment phases.</td>
<td>• ← LPA: customized extended cockpit environment for integration (platform 3) • RA: customized extended cockpit for regional • Other IADPs : tbd • TE, ECO: see section 11.7.</td>
</tr>
</tbody>
</table>

**SESAR, NEXTGEN interface**

The compatibility of *Clean Sky 2* work with the overall principles and recommendations of SESAR and NextGen is an overall objective to be met all through the programme. This objective is even stronger in Extended Cockpit where direct implementation of SESAR regulations will be performed (in displays, procedures, communications, trajectory management, …) A dedicated work package will be set up to interface SESAR (and possibly NEXTGEN) in close collaboration with the Clean Sky JU; Extended Cockpit will be one of the main activities of this WP. Please refer to section 11.7 for a short description of this WP.
11.6.1.2 Technologies and Building Blocks – WP1.2, 1.3, 1.4

I. Cockpit Display Systems

a. Background – Clean Sky activities

There are no specific Cockpit Display activities in Clean Sky. However, some of the programme activities have direct impact on HMI (green trajectories, for example). Many other collaborative R&D programs are focused on cockpit topics. Their results will be taken into account in Clean Sky 2 work. Further, the step changes needed to implement SEAR and NextGen concepts, the overall evolution of systems and the never-ending improvement of safety call for significant innovations in cockpit design.

Finally, the radically new IADP designs and the advanced integration and demonstration level they target will call for specific, breakthrough designs to be developed in the Systems ITD and later customised for and integrated in the target IADPs.

b. High-level objectives

Evolutions of Cockpit Display Systems are a needed enabler for future evolutions of air transport, new flight procedures and new aircraft architectures. As for FMS, developments in Clean Sky 2 will target both short-term evolutions for IADPs needs and long-term innovations to implement new architectural concepts, innovative HSI devices and crew efficiency enablers in flight management and systems management areas.

- Mid-term evolutions include:
  - Large screens, tactile, haptic interface
  - Configurable display
  - “Eyes-out” capacities based on head-up display (HUD) evolution (bichromatic)
  - Data fusion
  - Ability to integrate open-world data and to connect to ground services

- Mid-term innovations include:
  - New integrated task-centric user interfaces helping the pilot to manage system complexity without having to know system architecture (piloting, mission management, system management...).
  - Breakthrough “Eyes-out” capacities (head-worn)
  - Reconfigurable IMA2G implementation
  - Adaptive display and workshare
  - Seamless cockpit for continuity of information, active area optimization
  - Virtualisation of hardware control panels in order to reduce size, weight & consumption and improve user-friendliness
  - Equivalent Vision Operation (EVO - enhanced vision and synthetic data)
  - New development framework to reduce development costs, facilitate customisation and evolution and implement roadmap towards incremental certification.

c. Expected high level added value per demo / techno wrt. H2020 objectives
Clean Sky 2 Joint Technology Initiative in Aeronautics

Target for Cockpit Display Systems are:

- To prepare and develop innovative displays and HMI.
- To integrate these results in the Extended Cockpit Demonstrator of the Systems ITD.
- To customise and deliver a complete crew environment for integration in IADP demonstrators.
- To prepare a similar approach for SAT domain through the evaluation of synergies with other aircraft segments and the fostering of dedicated systems development when a specific approach is needed.

Contribution to H2020 objectives will be:

- Flight safety will be enhanced through greater integration and higher crew awareness.
- New eyes-out and Combined Vision Systems will secure operational credits for approach and landing in all conditions.
- Virtual management of systems, use of lighter, more efficient technologies, elimination of paper documentation, etc. will simplify maintenance, reduce weight and reduce down operational costs.
- Proposed developments and collaborations will help secure the current market share of European manufacturers and open opportunities for research and future business for the European supply chain and Academia.

d. Interaction and interfaces with other ITDs / IADPs / TE / ECO and within ITD Systems

<table>
<thead>
<tr>
<th>Operational WPs</th>
<th>Inputs/Outputs in ITD Systems</th>
<th>Inputs from other ITD/IADP</th>
<th>Output to other ITD/IADP</th>
</tr>
</thead>
</table>
| WP1.1           | • Work and deliverables to be integrated in the “extended cockpit” demonstrator  
                  • Specific adaptations for SAT to be taken into account | • LPA, RA, FRA: requirements and airframer-level constraints. Preliminary guidelines for needed customization. | • directly via extended cockpit integrated demonstrator  
                    • Specifically for customized parts.  
                    • TE: see section 11.7  
                    • ECO: engineering/production elements. See section 11.7. |

e. Planning

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Demonstrations / Activities</th>
</tr>
</thead>
</table>
| Cockpit Display System | • New crew environment  
                          • Virtualised systems management  
                          • HIS framework for faster to develop, customisable HSI  
                          • Incremental certification |

![Diagram showing technology development timeline and TRL levels](image)
II. **Flight Management**

a. **Background**

A significant part of the *Clean Sky* “System for Green Operations” ITD is devoted to Management of Trajectory and Mission activities. At mid-programme, current assessment of these new green trajectories and flight management functions show significant environmental gains for fuel consumption and CO₂ emissions in all flight phases as well as perceived noise in airport areas.

b. **High-level objectives**

The strong results shown in *Clean Sky* confirm the need to further develop the flight management functions in order to:

- Reach TRL 5 or 6 for all functions;
- Optimise green trajectories for new aircraft configurations as foreseen in *Clean Sky 2 IADPs*.

There is also a need to adapt the HMI of the new functions for future cockpit configurations in order to automate operations, reduce crew workload and maintain environmental benefits in all conditions.

Beyond the green trajectories pioneered in *Clean Sky*, innovative flight management procedures and functions will be needed in order to implement SESAR/NextGen recommendations, enhance safety through surveillance and communication functions, optimise taxi phases, etc.

There is also a trend to extend the capabilities of the FMS in order to:

- help the crew prepare for mission changes, forced or decided for optimisation purposes,
- prepare route changes (weather hazards, adverse winds or wind surfing, ...)
- Adapt to failures or airworthiness changes
- Adapt to crew capacity
- Help the crew or the ATC system control the mission not only in terms of way points and flight levels, but also in terms of headings and other aircraft trajectories.
Flight management plays a central role in aircraft performance, crew assistance and flight safety. In **Clean Sky 2**, two development threads will prepare on one hand the flight management systems needed for the flight tests of the IADPs demonstrators and on the other hand longer-term innovations to adapt to the transformations of the ATM system.

The **Clean Sky 2** development will address the following topics:

- **Mid-term “innovative” evolutions:**
  - Mandatory evolutions to insert the aircraft in the traffic with greater precision, implement high performance functions requested by SESAR, optimise crew interface and automate high-precision approaches in all conditions.
  - Needed changes to take into account future aircraft needs and IADPs requirements. The new aircraft matured in **Clean Sky 2** will need significant changes to optimise flight, adapt to new architectures, display systems and operational conditions.

- **Mid-term breakthrough:**
  - Crew efficiency: develop flight management human-system interfaces and crew awareness of current status, ATC situation and alternatives to current flight. Prepare “safety nets” and flight operations environment for reduced crew operations.
  - Interface with systems: interface FMS with other aircraft systems to give the crew a complete and realistic status as well as a realistic forecast of the remaining flight phases.
  - Prepare automatic trajectory negotiation with ground ATM systems based on these forecast capacities; move from Flight management to Mission management.
  - Adapt to future avionics architectures in display, systems interface and management, computing and graphic platforms.
Move to new development frameworks and environments in order to reduce development costs, facilitate customisation and evolution and implement roadmap towards incremental certification.

c. Planning

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Demonstrations / Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Management</td>
<td>• Green trajectories&lt;br&gt;• SESAR, nextgen integration&lt;br&gt;• Interactive FM</td>
</tr>
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</table>

Note: Several development plannings will be taken into account. This will allow taking into consideration:

- The number of different, parallel developments to be integrated (i.e. different functions, or green trajectories developed in parallel), and the various maturity levels reached so far (in Clean Sky, for example).
- The different timelines foreseen for the various target aircraft
- The wish to address immediate needs (TRL 5 in 2016) and future step-change concepts with more potential for innovation (TRL5 in 2020+)

III. Advanced functions

a. Background

A significant part of the Clean Sky “System for Green Operations” ITD is devoted to Management of Trajectory and Mission activities. While advanced functions are not directly addressed in the programme, many Flight Management improvements call for significant evolutions in communication, surveillance and systems management functions.

Innovative functions such as datalink, weather surveillance, mission management, etc. will also play a key role in the implementation of most SESAR improvements.

This work will build upon existing and expected results from other collaborative projects: French National Projects, ALICIA, SANDRA and followers.

b. High-level objectives

Beyond the green trajectories pioneered in Clean Sky, innovative flight management procedures and functions will be needed in order to implement SESAR/NextGen recommendations, enhance safety through surveillance and communication functions, optimise taxi phases, etc.

Finally, the new aircraft configurations developed in Clean Sky 2 will drive the development and integration of new systems management approach with a view to reduce weight and complexity of control panels, new flight safety functions including surveillance, weather management, etc.

This defines the scope of the proposed activities and demonstration for advanced functions.
Advanced Functions will provide new operational capabilities to complement Flight Management benefits. They address the full mission sequence, gate-to-gate, in the areas of Systems Management, Communication, Navigation, and Surveillance:

- **Ground-to-board and A/C to A/C communication**

  New environmental targets, increasing traffic and future Air Traffic Control procedures as foreseen by SESAR, NextGen, etc. will lead to a dramatic increase in A/C communication needs. Future aircraft will access and contribute data as active nodes on the future ATM global network. Voice communication with pilot-in-the-loop will progressively be replaced by digital exchanges (datalink) with pilots as validators.

  Examples of new procedures are: negotiation of optimized flight trajectory or taxi route with ATC, exchange of passenger information or maintenance data with AOC, etc.

  New communication standards have been prepared and should become mandatory in the coming years.

  These major changes call for a new, integrated, versatile communication management system and function to be matured and integrated in **Clean Sky 2**.

- **Surveillance (protection – Separation) in all flight phases:**

  - **Weather surveillance:** data fusion of on-board, other A/C and ground sources, new weather models for forecasts, and improved communication means will increase the reliability of weather information proposed to the crew and taken into account into the aircraft systems. This will enable new system capabilities such as automatic weather avoidance trajectory, runway contamination measurement and transmission from aircraft to aircraft and braking adjustments.

  - **Terrain surveillance:** terrain databases, new sensors and improved navigation systems will improve safety in critical situations (e.g. crew assistance or fully automatic 3D terrain avoidance), and enhance crew awareness – primarily in TMA zones, in all conditions. Approaches (for example runway overrun) and taxi operations (obstacle avoidance) will be secured.

  - **Aircraft separation** will cover automatic avoidance of wake vortex, optimal separation between approaching aircraft, crew information and supervision. Automatic self-separation based on ADS-B will also be developed, with a view to assist crew and reduce workload for controllers.

- **Systems Management**

  Failure situations often lead to increased stress and workload for the crew. The root cause of complex failure situations may be difficult to identify, as current systems management functions are not fully integrated. Also, these functions are systems-oriented, while the primary need of the crew is an operational view: what is the impact of the reported failure on immediate flying capacity, on short-term situations, on the remaining part of the mission? What are the alternative routes, options? What are their consequences? Work on this topic in **Clean Sky 2** Systems ITD will focus on:

  - **Simplified, more intuitive view of systems status, failures, associated procedures, etc.**
o Transition from system-oriented to capability-oriented assessment and crew information.
o Automated systems management and mission-oriented crew support and assistance.

- **Mission Management**

Individual advanced functions will ultimately be consolidated and integrated to provide full mission management capabilities, taking into account flight plan and trajectory, surveillance data, ATC and ground information, systems situation and aircraft capabilities. This synthetic approach will provide the crew at all times with a full view of the current situations, identified events, open alternatives and their consequences.

c. **Expected high level added value per demo / techno wrt. H2020 objectives**

Target for Advanced Functions are:

- To prepare and demonstrate significant gains in operational capabilities, pave the way for SESAR implementation.
- To integrate these results in the Extended Cockpit Demonstrator of the Systems ITD.
- To customise and deliver a complete crew environment for integration in IADP demonstrators.
- To prepare a similar approach for SAT domain through the evaluation of synergies with other aircraft segments and the fostering of dedicated systems development when a specific approach is needed.

Contribution to H2020 objectives will be:

- Flight safety will be enhanced through surveillance and capability-oriented systems management.
- New com functions will be SESAR-ready.
- Proposed developments and collaborations will help secure the current market share of European manufacturers and open opportunities for research and future business for the European supply chain and Academia.

d. **Interaction and interfaces with other ITDs / IADPs / TE / ECO and within ITD Systems**

<table>
<thead>
<tr>
<th>Operational WPs</th>
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| WP 1.2 & 1.3    | • Work and deliverables to be integrated in the “extended cockpit” demonstrator  
• Specific adaptations for SAT to be taken into account  
• Additional functions proposed by core partners could be developed and integrated in the demonstrator.  
| • LPA, RA, FRA: requirements and airframer-level constraints. Preliminary guidelines for needed customization.  
| • directly via extended cockpit integrated demonstrator  
• Specifically for customized parts..  
• TE: see section 11.7  
• ECO: engineering/production elements. See section 11.7. |
IV. Platform & Networks

a. Background

*Clean Sky* does not address Integrated Modular Avionics (IMA) or networks topics. However, recent and current European and national collaborative research programs are preparing the next generation of aircraft platforms (SCARLETT, ASHLEY, French and German national programs). These programs will produce significant output in a schedule compatible with *Clean Sky 2* integration timelines.

In parallel, the avionics platform domain is facing major technical, industrial and economic challenges:

- The increasing complexity of modern avionics, the volume of data and the computing power needed to optimise flight operations in a SESAR based global Air Transport System call for new concepts and architectures.
- The sustained evolution rate of new functions, applications, additional data, new connections, call for a modular logical architecture for Avionics, with emphasis on easy upgrades, dynamic implementation and incremental certification.
- These objectives and the growing competition in the field drive new approaches to optimise these systems: COTS integration (multi-core processors, graphics generators), versatile multi-platform building blocks, etc. to address as many aircraft types as possible
- New threats have appeared: jamming, hacking, data modification or corruption, etc. The growing interconnection of future aircraft and the needed capacity to update/upgrade operational software call for dedicated protections and processes to guarantee safety through security.
- Finally, the increase in computing power, throughput and complexity should be obtained with lower weight, power consumption and thermal dissipation than in current architectures.

b. High-level objectives at demonstrator / technology levels

The overall performance and versatility of the avionics systems of an aircraft are a direct consequence of the modularity and scalability of the underlying computing platform and communication networks. The introduction of IMA in modern aircraft has already led to the standardization and virtualization of functions as independent software modules running on standardized computing and communication resources. The clear benefits of this approach are a strong incentive to apply the IMA approach for the next generation of aircraft platforms and extend IMA concepts to non-avionics domains such as cabin domain and critical systems.
Expected gains will include:

- Weight reduction thanks to optimised use of shared common platforms and reduction of the number of actual primary equipment and backup. This weight reduction will yield fuel consumption and CO₂ emission benefits.
- Weight reduction through work on packaging, including innovative, exploratory work on composite or magnesium based packaging.
- New approach to COTS use in avionics system: multicore processing units, dedicated, “system-on-chips” approach, high-speed optical networks, etc.
- Easier update of existing applications and easier introduction of new elements in the aircraft architecture, allowing better implementation of new procedures and functions during the lifecycle of the aircraft. SESAR, NextGen, are probably only the first of examples of industry-changing standards that will have a major impact on the operation and equipage of aircraft. The capacity for retrofit is a new challenge for new aircraft.
- Lower costs of maintenance, higher availability of aircraft.
- Lower production costs as a result of higher production rates of less part numbers.
- Simplified certification process thanks to the separation of hardware and software issues.

c. Description of added value of the demo / techno vs. state of the art

*Clean Sky 2* “extended cockpit” activities will focus primarily on functional and operational innovations. For lower TRLs and early developments, ad hoc test sets might be sufficient to assess work results and demonstrate feasibility of proposed innovations.

Conversely, IMA work could be “limited” to hardware and software ad hoc demonstrations, building on SCARLETT, ASHLEY and other collaborative programmes results in order to introduce new concepts and building blocks.

However, *Clean Sky 2* is clearly focused on high TRL / integrated platform demonstrations. In this perspective, the best way to facilitate the integration of systems developments into IADP demonstrators is to use as a common platform the emerging standards of IMA and communication. This step will further enable the integration of parallel developments into a single demonstrator and prepare the ground for global, platform-level assessments. In addition, the resulting system will be easier to take into consideration for the implementation assessments such as thermal, weight or electrical consumption.

The main objective of the platform & network activities will therefore focus on the preparation and qualification of a full IMA platform to host extended cockpit hardware and functions.

Key activities in this section will address:

- Platform architectures: optimized switchless architectures, distributed architectures, IO concentration, dissimilar networks, IO versatility,…
- Hardware technologies: high-performance graphical units, mass memory performance, multicore processing units,…
- Development Environment & tools: platform services integration, graphics generation tools, certification issues (for multicore, …), simulation for EMC & mechanical aspects, …
- Packaging, lightning protection, …
- Virtual and hybrid demonstration methodologies to allow for progressive integration of actual hardware in COTS-based environments.

d. Planning

Planning in this activity will be defined in relation with the target architectures identified for the demonstrators (see below), with a view to deliver adequate demonstration environment to the main demonstrators. Overall, platform activities will be driven by demonstration needs and should address three temporal targets:

- “Quick wins” for maturation of work performed in current and previous European and National research projects
- First wave of demonstrations for mid-program demonstrations and earliest branch-out for some IADP targets
- Extended Cockpit platform

e. Interaction and interfaces with other ITDs / IADPs / TE / ECO and within ITD Systems

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• Specifically for customized parts.  
• TE : see section 11.7  
• ECO: engineering/production elements. See also section 11.7. |
1.6.1.3 Demonstrations – WP 1.4 & WP1.5

Demonstration activities will be divided in three parts:

1. Extended Cockpit: will be the baseline of the demonstration activity, with a view to integrate and assess a fully representative cockpit in realistic environment, including operational evaluation with crew-in-the-loop.

2. IADP-targeted demonstrations will depend on the specificities of the IADP cockpit as defined in WP 1.1. These demonstrations will be performed either in the Systems ITD or in the target IADP, to be detailed in a later phase after WP 1.1 conclusions.

3. Ad hoc demonstrations will address technologies that cannot be integrated in the main demonstrations above, due to low TRL, disruptive concept and/or specific demonstrations needs.
11.6.2 Cabin and Cargo Systems

Based on high-value unsolicited expression of interest received in the context of Clean Sky 2 definition, it is foreseen that Cabin & Cargo Systems should be a significant activity in the Systems ITD. This WP will be defined and organised during the Core Partner formal selection phase, its content will be updated in a later version of the document.
11.6.3 Future Electrical Wing – WP3

I. Innovative Electrical Wing (IEW) for Regional Aircraft

a. Background – Clean Sky activities

Safran has been involved in various Clean Sky SFWA Work Packages which have achieved interesting results on following items:

- A complete simulation model has been performed inside the SFWA project. This model deals with wing measurement during simulated flight with the main goal to integrate this new information in the A/C Flight Control System. It has been demonstrated that an Inertial Measurement Unit (0.1 °/s class) integrated in the wing structure is an innovative solution, that will be evaluated with flight tests trials on A320 in 2015. This technology could be used for future dynamic monitoring of the wing during A/C operations (fatigue, structural health monitoring, etc.). In order to validate this potential use, it will be necessary to validate models with flight tests results and validate level integration in an A/C system (FBW, FCS, Navigation ...).

- Contribution to the development of electric system architectures for Data-communication On Power networks (DOP).

- The main advantage of this technology is to reduce the number of cables: 3 twisted pairs of cable replaced by one twisted pair, only dimensioned for power transmission. Indeed a HVDC network: 540Vdc (peak voltage up to 700V) and load consumption from a few kW up to 10kW have been tested with no damage. Validation of a cable length up to 36 meters is achieved.

- This DOP technology can be improved in the context of Innovative Electrical Wing.

In the IEW project, Safran will take into account the results from some European Project like Actuation 2015 (A2015) and SCARLETT. In the A2015 project, the main goal is to define a' modular approach” in order to develop some standardized components for EMA's, whatever their functions are (e.g. Flight Control, Landing Gears...),like Motors, Electronics (Power Drive &Control), sensors .As far as possible, these results will be reused in the IEW project. Safran is responsible for Test & Validation benches of some EMA’s, and /or components developed in the of A2015 project. They could be reused for Motor/Electronics/sensors integration & validation of EMA's, wrt Regional Aircraft IADP goals in Clean Sky 2. As far as SCARLETT project is concerned, Safran is anticipating some reuse of results in the field of the IEW ‘Global Health Monitoring’. 
b. High-level objectives at demonstrator / technology levels

The “Innovative Electrical Wing” project intends to propose an optimum solution for a complete flexible and thin wing using mainly electrical technologies, focusing in Clean Sky 2 on a regional aircraft configuration. Mainly secondary actuators are considered, as well as high lift systems. New principles of electrical synchronization and distributed architectures will be proposed. Some primary actuators like Spoiler/Rudder could also be investigated.

Actuation, energy distribution through innovative electrical networks, health monitoring solutions, will permit an optimal control of such future wing that will have more and more carbon fibre elements, at structural level. The systems wiring of this new type of carbon fibre wing will address potential field busses, using for instance optical fibre. Wi Fi technologies could also be addressed.

The concept will cope with systems architectures, permitting to achieve safety goals and aircraft certification, possibly by introducing a ‘trans-ATA’ approach.

The main objectives of the Programme are as follows:

- Maintain an equivalent level of safety and performance,
- Reduce the total weight at aircraft level,
- Increase the availability of functionalities, and eventually add some new ones,
- Simplify maintenance operations to optimize ownership total cost,
- Take into account ACARE objectives.

In order to achieve all these goals, federating various technologies and methodologies, many challenges will be faced, at three levels: system, equipment and technology.

The evaluation and integration de-risk of candidate technologies contributions can be feasible using physical and/or virtual platform (Hardware-Software in The Loop, Co-simulation). The System Engineering approach will improve mastering Flight Control System increasing complexity. Cooperation with the R-IADP is foreseen.

To achieve these goals, the following aspects will need to evaluate and analyze:

- the introduction of dedicated inertial sensors to monitor and control the flexibility of wings, by introducing new sophisticated control laws in the FBW system to allow a better optimization of the flight, reducing drag and thus fuel consumption;
- the mechanical definition of new wings in terms of actuation sub-systems (Electrical Actuators) for primary and secondary Flight Controls;
- the capability to develop innovative electrical networks (e.g. energy and data distribution, DOP);
- the high integration level of Drive & Control Electronics, whatever the type of actuator. Harsh environment will be considered, as well as reliability over a large range of temperatures;
- the capability to integrate dedicated sensors and optimized electrical motors in Electro Mechanical Actuators, with the aim to reduce mass and volume to respect the environmental constraints of future thin and flexible carbon wings;
- the future Health Monitoring functionalities to be integrated at actuators and sub-system levels.
c. Description of added value of the demo / techno vs. state of the art

Economical (mainly due to ever increasing price of fuel) and environmental (like fuel burn particles rejection or use of pollutant hydraulic fluids) constraints push for a need of more electrification and energy optimization in the embedded systems of the aircraft. As a main consequence, their complexity is growing rapidly and simultaneously.

Electrical systems, compared to equivalent hydraulic ones, show high gains in safety, reconfiguration and maintenance. Nevertheless, at present stage, they still demonstrate a bigger mass and less reliability. One of our main goals is therefore to work in priority on these two key design drivers, without forgetting cost aspects. In addition, higher life duration of future EMA’s must be demonstrated.

One of the main levers to reduce fuel consumption at aircraft level is to increase the efficiency of actuation power systems. Today, they are mainly supplied through hydraulic circuits, of which pumps are driven by the engines, and by pneumatic circuits taking the pressurised air from the engines as well. Those various circuits, with a quite poor efficiency ratio, permanently supply power which is leading to some large energy loss.

Replacing those circuits by new electrical networks will permit to increase considerably the aircraft systems efficiency, and as a consequence diminish fuel consumption at engine level, mainly if it is possible to integrate “power on demand” strategies at electrical systems level.

Flexibility, easy to install and possible self-monitoring of electrical systems will allow targeting important gains about acquisition and exploitation costs.

Electrical architectures will imply a new system approach at aircraft level, taking into account more and more stringent requirements for availability and maintainability. New control modes, new distributed actuation solutions or mutualisation of power electronics for instance, are emerging. At the same time, certification constraints and systems validation are going to evolve, thanks to the aircraft electrification increase.
### d. High-level plan with schedule, major milestones, deliverables, TRL to target

<table>
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<tr>
<th>Domain</th>
<th>Technologies</th>
<th>Demonstrations / Activities</th>
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<td>INNOVATIVE ELECTRICAL WING</td>
<td>High integration Drive &amp; Control electronics. Optimized Smart actuators</td>
<td>Actuators network EMA Primary &amp; Secondary</td>
</tr>
<tr>
<td></td>
<td>Dedicated inertial sensors on A/C structures</td>
<td>Flexible modes monitoring and control of new wings. Global health monitoring</td>
</tr>
<tr>
<td></td>
<td>Electrical Networks (energy and data distribution)</td>
<td>1 demo at Sagem, 1 demo on COPPER Bird®</td>
</tr>
<tr>
<td></td>
<td>Systems integration (incl. HW SW IL)</td>
<td>Demonstration on dedicated benches (Iron Bird) by Sagem</td>
</tr>
<tr>
<td></td>
<td>Wings architecture systems studies</td>
<td>Modelling activities. Virtual integration</td>
</tr>
<tr>
<td></td>
<td>Avionics &amp; FCS new control laws for flexible modes, new functions</td>
<td>Architectures trade offs &amp; specifications</td>
</tr>
</tbody>
</table>

![High-level plan with schedule, major milestones, deliverables, TRL to target](image)
### Innovative Electrical Wing for Regional Aircraft

#### Participation of:
- **Alenia**
- **Safran**
- **Core Partners / Partners**

#### Regional Aircraft IADP
- **Alenia**
- **Safran**
- **Core Partners / Partners**

<table>
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<tr>
<th>Work Package</th>
<th>Innovative Electrical Wing for Regional Aircraft</th>
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<tr>
<td>WP 3.2: Flight Control System Component Technologies</td>
<td>Reporting / Results / Dissemination</td>
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<tr>
<td>WP 3.1.1: Wing Systems Architecture for Regional Aircraft</td>
<td>WP 3.1.1.1: System &amp; Real Time Architectures, virtualization / modeling &amp; optimization, including Health Monitoring req</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>WP 3.1.1.2: Electrical Networks (Energy &amp; Data Distribution)</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>WP 3.2.1: Innovative Wing System Sub-Assemblies-Technologies development for Regional Aircraft</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>WP 3.4.3: Demonstration objectives . Test Plans definition</td>
<td></td>
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</table>

**Link in RA IADP**
- WV1, WV4, WV5 (EPGDS)
- WP4.1
- WP2.3.4 (EPGDS), WP3.1, WP3.3, WP3.4, WP3.5.4
- WP 3.1, WP 3.4.4, WP3.4.5, Flight Control System WP3.3.3, WP3.3.4

**N.B:** discussions with Alenia-Aermacchi with regard to Regional Aircraft IADP (R-IADP) synergies are on-going.

The final demonstration will be performed on the COPPER Bird® (ITD Systems WP 6.4.1), and in synergy with the Innovative Electrical Network project (ITD Systems WP 5.2.1) which will be also integrated on the COPPER Bird®. With respect to WP3 Sagem IEW project, it will be necessary to think about partnership with some competences in the following fields: simulation and virtualization, multi-physics, technologies (power and control electronics, fine mechanics) .European Universities, specific laboratories , SME’s could apply for dedicated calls to strengthen Sagem proposal. Moreover, Sagem IEW project will need competences in designing, realizing and validating a complex V&V test bed (incl. HMI) with strong real time constraints.
f. Expected high level added value per demo / techno wrt. H2020 objectives

Define and develop new actuation architectures for a new thin, flexible, and more carbon wing concept will imply 5 main goals which have been identified in relation with the R-IADP:

1. Optimize the fuel burn through a better active control of wings behaviour, for the whole flight
2. Reduce weight at A/C level, by designing/anlayzing wings definition and “s-systems requirements”, Actuation-FCS, EWIS, Data Networks, Energy Distribution
3. Removal of environmental unfriendly fluids, as far as possible
4. Increase the usage and simplify the maintenance of the Aircraft, thanks to new algorithms for Health Monitoring
5. Need for a new approach for certification, taking into account EWIS and Energy Distribution interfaces and constraints, in a More Electrical Aircraft (cf trans ATA)

The “Innovative electrical wing” project will address many different technologies and architecture / systems studies:

- Systems engineering approach
- Smart actuators for Primary and Secondary FCS
- Inertial sensors
- Innovative electrical networks
- Drive & control electronics
- EMA health monitoring

**System Engineering**

The final goal is to define and validate a “System and Safety Engineering Platform “ that permits to specify (through Requirement Based Engineering – RBE), design, simulate any Flight Control System architectures and to interface these outputs directly with other physical models, like thermal, mechanical vibrations, EMI/EMC environmental conditions..., to ease and accelerate the global design of the FCS itself, and simultaneously through a complete virtualization process to increase the maturity of the equipments that form the final system.

**Inertial sensors**

Another type of innovation level should appear with the generalization of dedicated inertial sensors usage due to more sophisticated Fly By Wire (FBW) control laws, with the wings flexibility increase. Such equipments encompassing robust inertial technologies appeared more than ten years ago on few large civil aircraft, and will probably be generalized for future programmes with new wings type development.
Secondary Flight Controls – Smart actuators

Electrical equipments and in particular electro-mechanical ones introduce new types of failure modes, like the electronics ones, mechanical jamming, effort limitation, non-natural damping, etc.

In general, these failure modes are quite different from what can be seen on hydraulic actuators. The design and development of Flight Controls EMA’s leads to many challenges such as: high integration of motor, bearings and roller /ball screws, very long life lubrication in severe environment, load measurement and control functions, optimized thermal dimensioning, standards software /hardware concepts, embedded compact power electronics, health monitoring of all critical parts.

Future aircraft programmes will rely on always more increasing electrification of their systems. In the field of secondary actuation systems, two main axes are investigated:

- Classical architecture with mechanical synchronization, but with the introduction of a ‘more electric’ Centralized Power Drive Unit; and
- Innovative architecture with independent electrical synchronization of all surfaces through dedicated EMA’s distributed control.

Innovative Electrical Networks

For a more electrical aircraft, power centers are designed to drive high power electrical loads, distribute power to secondary boxes, power local networks or create other network (115V / 400 Hz). Multiple electrical loads have been identified as eligible high power equipments: flight controls actuation, engine start, APU start, landing gear extension / retraction, etc.

The main functionalities of such Innovative Electrical networks are : Energy Management & Optimization, Networks stability, Energy Conversion and Storage, Reversibility, Weight saving at A/C level.

Several challenges must be tackled, such as safety, reliability and dispatch requirements improvement, EMI/EMC new composite wings and structures, wings network sensors and actuators, reversible DC network stability and performance, installed power reduction and aircraft wiring optimization, data and power coupling on field busses.

In addition, the wiring aspect is a major element to improve future electrical systems (EWIS). Various items will appear in order to facilitate and modularize definition and manufacturing. The introduction of optical fibers in bi-directional networks, using proven data exchange protocols, will allow interconnected actuators and computers networks in harsh electromagnetic environment (HIRF, EMC, etc.), data integrity verification in high frequency communications, system dependability optimization of a complete A/C architecture. The main goal is to demonstrate robustness of all these networks, installed on composite structures.
**Drive & Control Electronics-Flight Control Computers**

The electronic part of an EMA is one of the main components to be optimized with respect to reliability and mass. This is necessary to achieve the right level of such key design drivers to make electromechanical technology competitive enough, regarding the hydraulic one. To drive the power demand from EMA’s, the main criteria is the ratio KW/Kg (Kilowatt per Kilogram), that will increase in the coming years, thanks to usage of new materials, and at the same time to innovate on thermal solution, at EMA level. On the control side, the aim is to miniaturize electronics as far as possible, and at the same time to be able to implement new software functionalities to control electrical motors and to increase the resources needed for achieving Health Monitoring objectives, like memories and data processing.

More generally all electronic components, by using new materials, must be able to perform against harsh environmental conditions, under severe vibrations and high temperature. Simultaneously, a high reliability must be targeted, in order to achieve stringent safety and availability goals, at system level.

**Electro Mechanical Actuator Health Monitoring**

The emergence of EMA technology paves the way for a new maintenance philosophy based on failure anticipation. The aim of Health Monitoring algorithms is to detect actuator degradation, before it leads to an actuator failure. When EMA degradation is detected by Health Monitoring functions, Airlines maintenance teams can plan unscheduled interruption to repair or replace the EMA in appropriate facilities, at a chosen time, with the minimum impact on aircraft commercial operations. The Health Monitoring functions are designed to avoid the failures that could ground the aircraft, such as actuator jamming or loss of actuator damping (depending on the actuator function in the flight control system). This function will enhance aircraft operational reliability.

The following benefits are foreseen:

- **Environmental**: Enabler for reduced wings drag, Weight saving, Fuel saving, Removal of environmental unfriendly fluids, reduce particles rejection, etc.

- **Competitiveness**: Reduced aircraft cost of ownership (DOC), minimized fuel consumption (with an ever increasing fuel price), simplified maintenance (plug & play concept), quicker integration and installation/tests onto the Aircraft with more electrical equipments (self-monitoring, acquisition cost), etc.

- **Societal**: Availability of functionalities increased, new functionalities added, better reversionary modes in case of failures=enhanced “graceful” Safety, and probably noise reduction and vibrations reduction in turbulence (better comfort for passengers), thanks to wings surfaces better control, etc.

**II. Smart Integrated Wing for Large Aircraft Demonstrator**
a. Background

The electrification of all respective systems in the wing and those which are attached to it has already been started. Studies have been done with respect to EMAs for Primary Flight Controls and health monitoring in German national funded R&T programs “KONKRET”, “FASY” and “ARISTO-KAT”. There were also activities in the European projects “POA” and “MOET” to support the more electric aircraft approach and the full electrical nose landing gear.

Some main objectives were:
- New functions for high lift systems (e.g. roll function)
- Self-sustaining high lift system (e.g. batteries)
- EMA for single-aisle aileron actuation
- EMA and EHA for regional jet landing gear actuation and steering
- New sensor systems and wireless communication
- Health monitoring for high lift and primary flight control
- Load monitoring for landing gear structure and actuation
- Skew avoidance concepts & systems
- Sequential and parallel power sharing converter

b. High-level objectives at demonstrator / technology levels

Within Clean Sky 2 it is proposed to design and test a new concept for a complete electrified wing based on electrical technologies. This includes new actuation system technologies for primary and secondary flight controls, as well as extension, retraction and up-lock of the landing gear system, and wing ice protection systems taking into account the requirements for advanced wing concepts. This multi-functional and multi-disciplinary concept will include cross-ATA system optimization and the demonstration of new system architectures on the wing section.

- **Electrical actuators for primary flight controls and high lift and power electronics**
  The main objective is to demonstrate a complete electrified actuation system for all primary flight controls (ailerons, spoilers) and the whole high lift system (leading and trailing edge) in the wing. But that’s not all. Also it is considered to mutualize the power electronics of the flight controls and the actuation of the landing gear system.

- **Control & monitoring architectures**
  To secure the above mentioned functions, there is a cross setting necessary between the secondary flight control computer and the landing gear control computer. Therefore the attached networks have to be optimized and combined. The new monitoring functions consist of a complete health monitoring of all attached actuators and power electronics, a load monitoring for all slats, flaps and the primary flight control surfaces to prevent overloads and failures and a failure monitoring, which is used to record non critical failures and system interrupts for an optional after-flight check. It is therefore planned to test a wireless ground monitoring system to establish a secure and fast method to check all actuation systems of the flight controls and the landing gear system.
o **Drive & control electronics**
Main objective is to demonstrate next generation drive systems with higher standards for safety and reliability and to introduce special customized control electronics for all drive systems. In addition to that it is intentionally planned to demonstrate an electrical wing power management for the whole electrified wing and all its components.

o **Electrical wing ice protection**
In terms of future laminar and thin wings, it mandatory to secure a wing ice protection system with a high level of reliability. Therefore it is planned to test and demonstrate an electrical wing ice protection system (eWIPS) which is fitted with respective sensors all over the leading edge and relevant surfaces and is linked to the above mentioned monitoring architectures. One of the main objectives is the challenge to integrate such a system into thinner leading edge structures and laminar wings. This technology will be demonstrated in WP6 Major loads and integrated on the Smart Integrated Wing Demonstrator.

c. **Description of added value of the demo / techno vs. state of the art**

o **Electrical actuators for primary and secondary flight controls including power electronics:**
The share and mutualisation of power electronics can bring a direct effort on weight and complexity reduction. This will result in less fuel burn, less maintenance and less operating expenditures. The electrification of all relevant system will complexly ban the hydraulic system from the wing and therefore will reduce the risk of leakages and the respective maintenance and operating costs.

o **Control & monitoring architectures:**
Monitoring all parts of the flight control and high lift system will result in benefits of less unscheduled maintenance and less AOG events. With an appropriate monitoring system, repair and overhaul activities could be scheduled more reliable and thus would reduce the operating cost of the system. Shared control architectures will significantly reduce the complexity and weight of state-of-the-art systems.

o **Drive & control electronics:**
Customized solutions for next generation electrical drive systems will reduce the needed space of actual systems and also the weight of action system with integrated drive systems. It will also raise the effectiveness of the whole actuation system.

o **Electrical wing ice protection:**
On laminar and thin wings it necessary to keep the surfaces clean and wing ice during flight and pre-flight is particularly a threat to thin and laminar wing. Therefore a reliable electrical wing ice protection system will raise the safety during flight and will also secure the effectiveness of the laminar flow over the wing. Smaller solutions for less space in laminar and thinner wing structures will also have a positive impact on the wing weight.

d. **High-level plan with schedule, major milestones, deliverables, TRL to target**
<table>
<thead>
<tr>
<th>Domain</th>
<th>Technologies</th>
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<tr>
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<td>Electrical Wing architecture concepts</td>
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<td>Power Electronics for sequential applications</td>
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<td>Electrical Wing power management concept</td>
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<td>Wing Systems Integration &amp; Demonstration incl. Actuation, LG and WIPS</td>
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[NH(C)44]
e. Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD

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<th>IADP LPA Participation of:</th>
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<td>WP 3.2.2: Sensor concepts and Health Monitoring</td>
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</table>

f. Expected high level added value per demo / techno wrt. H2020 objectives

- **Societal/ efficient and green transport:** Technology enabler for reduced wing weight which result into reduced fuel consumption and CO₂ emissions

- **Competitiveness:**
  - Strengthening of the European supply chain through bundling of larger packages consisting of system and structure components;
  - Enabler for lean assembly - reduced assembly time in the final assembly line through provision of pre-assembled ‘plug & fly’ wing structures.
III. Structure Integrated System Demonstrator

a. Background

In the frame of the German national funded project called “HISYS” has been developed an innovative carbon fibre flap track which carries the flap extension-retraction mechanism based on a side-attached Geared Rotary Actuator (GRA).

The existing Flap Geared Rotary Actuator (GRA) technology for large aircraft is the side-attached concept. The GRA is mounted on one outer side of the Flap track. The transmission down drive is realized by separate gearboxes and shaft on the opposite side of the track. This means that outside the Track additional envelope needs to be foreseen for the mentioned equipment, which needs to be covered by the fairing. This requires a certain width of the fairing and therefore aerodynamic disadvantages.

b. High level objectives at demonstrator / technology levels

The Structure Integrated System demonstrator project aims at developing a pre-assembled ‘plug & fly’ module of a flap actuation system already integrated into a structural part of the wing, the so-called flap track. The ultimate target will be a higher integration of components and sub-assemblies into the wing structure to cope with new weight and integration requirements for the next generation of short-medium range aircraft.

These requirements will be addressed by coping with the following challenges in the frame of Clean Sky 2:

- New actuator designs for improved track assembly and performance of the actuator;
- Actuators integrated into a CFRP track to minimize the width of the
fairing;
- Mature a full scale demonstrator including flap track and spoiler functionality;
- Provide solutions for the certification strategy of structural elements in combination with system components.

c. Description of added value of the demo / techno vs. state of the art

Nowadays structural sub-assemblies and actuation systems or components are mainly delivered as single equipment to the wing assembly line of the aircraft manufacturer to construct the wing on site of these materials. If now the wing assembly site would receive pre-assembled wing structure elements, several advantages could may be generated by using this “pre-fabrication” approach:

- Reduction of assembly time and congestion on wing manufacturer site, especially in high volume aircraft programmes;
- Reduced supply chain effort for the wing manufacturer;
- Weight reduction through higher integration in the pre-assembled tracks;
- Reduced aerodynamic drag of the flap track and the fairing through structural integrated actuators;
- Less number of parts, enables same P/N for LH/RH application;
- Higher functionality through integration of different flight control function into the pre-assembled track.

d. High-level plan with schedule, major milestones, deliverables, TRL to target

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<td>Prototype System</td>
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Major milestones:
- Actuator Design and Flap track Design Review - TRL 5 2015
- Demonstration of an integrated flap track – TRL 5 2017
- Demonstration of integrated flap track including spoiler flap – TRL 5 2020
e. Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD

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<thead>
<tr>
<th>Structure Integrated System</th>
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<td>WP 3.4: Demonstration</td>
<td>WP 3.4.2: Structure Integrated System Demonstrator</td>
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f. Expected high-level added value per demo / techno wrt. H2020 objectives

- **Societal/ efficient and green transport**: Technology enabler for reduced wing size, drag and weight which result into reduced fuel consumption and CO₂ emissions.

- **Competitiveness**:
  - Strengthening of the European supply chain through bundling of larger packages consisting of system and structure components
  - Enabler for lean assembly - reduced assembly time in the final assembly line through provision of pre-assembled ‘plug & fly’ wing structures
  - Reduced supply chain cost for the aircraft manufacturer
IV. Advanced Electrothermal Wing Ice Protection System

a. Background – Clean Sky activities

In the frame of Clean Sky SGO WP 2.3.4.3.1.1, several key technologies are developed to address the needs for future Wing Ice Protection System (WIPS) on large aircraft. A solution based on electrothermal approach was carried out by LIEBHERR in collaboration with SONACA to replace existing pneumatic systems, with the following objectives:

- Definition of system architecture and appropriate ice protection strategies
- Development of a ground demonstrator to:
  - Validate the performance of the system under known icing conditions (tests conducted in full scale Icing Wind tunnel)
  - Evaluate system required power according to protection strategy and spanwise/chordwise extension of the protected surfaces of the leading edge
  - Validate ice protection system control and monitoring principles

- Development of flight test demonstrator:
  - To check transient operation impact to validate the heating strategy
  - To assess environmental & structural compatibility, reparability and maintainability

The benefits of having anti-icing and de-icing functionalities were also investigated. Completion of these different studies and demonstrations will achieve TRL5 capability in the end of Clean Sky SGO. However, the approach conducted so far on thermal E-WIPS can be improved with optimization of structure/system integration and by optimizing the protection strategy. The solution developed within CS1 was optimized regarding the power consumption, but other criteria as reliability and maintainability are as critical in order to keep electrothermal solution competitive compared to pneumatic solutions. This key issue will be addressed within Clean Sky 2 to get a promising and robust system addressing whole aspects such as performance, power consumption, maintainability, installation and structural analysis.

b. High level objectives at demonstrator / technology levels

The next step Clean Sky 2 will be the development and validation of an advanced electrothermal Wing Ice Protection System corresponding to future needs for a single aisle. This is study will take the lesson learnt form Clean Sky (1) in order to consolidate the specification with the airframer support.

The proposed objectives are as follows:

- Definition of ice protection strategy according to airframer expectations
- Design of the relevant electrothermal wing ice protection system for Large aircraft based on preliminary work performed in JTI Clean Sky with focus on:
  - protection strategy (anti-ice/de-ice) to get the best compromise between power consumption and reliability objectives
  - system/structure integration to improve maintainability objectives

- Trade-off on new wing configurations defined by Airframers (laminar wing, etc.)
- Optimization of ice protection technologies according to performance requirements (power density, high voltage power supply, etc.) and robustness objectives (environmental constraints, lightning effects, etc.)
- Optimization of monitoring and control strategy
- Introduction of Health Monitoring functions to improve the maintainability and reparability

| CS1 | Trade-off for optimized electrothermal WIPS |
| CS1 | Consolidation of Ice protection strategy |
| CS1 | Development of ground demonstrator for IWT tests |
| CS2 | IWT tests including SLD |
| CS2 | Validation of electrothermal WIPS architecture |
| CS2 | Implementation of Health monitoring functions |
| CS2 | Development of a flight test demonstrator |
| CS2 | Qualification tests |
| CS2 | Development of an electrical test bench (PROVEN) |
| CS2 | Flight tests campaign |

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<th>2014</th>
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| **c. Description of added value of the demo / techno vs. state of the art**

Development of new architectures for Wing Ice protection system based on electrical technologies is a key issue to enable bleed removal for a better engine power exploitation.

Up to now, electrothermal WIPS seems to be the most electrical mature solution, but is still heavier and offers less availability compared to existing solutions, which reduce significantly the expected benefits at A/C level.

Therefore, the optimization of electrothermal WIPS architecture together with improvement of de-icing technologies and monitoring capabilities, will contribute significantly to make this solution competitive.

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| **d. High-level plan with schedule, major milestones, deliverables, TRL to target**

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| **e. Interaction and interfaces with other ITDs / IADPs / TE / ECO within the Systems ITD**

2014 Clean Sky 2 Joint Technical Programme (V4) – Proprietary Information subject to Confidentiality Agreements
Operational WPs | Inputs/Outputs in ITD Systems | Inputs from other ITD/IADP | Output to other ITD/IADP
--- | --- | --- | ---
WP6.2 | ↔ WP100.1: Power electronic | ↔ Airframe: Line A | → Airframe: Line A
| ↔ WP6.4: Test facility GETI | | → TE: Relevant inputs for models

f. **Expected high level added value per demo / techno wrt. H2020 objectives**

- **Environmental:** Fuel consumption reduction by operating modes and weight savings
- **Competitiveness:**
  - Reduction of operative costs by improving reparability and maintainability capabilities
  - Increase A/C availability through integration of health monitoring functions
11.6.4 Landing Gears Systems – WP4

I. Main Landing Gears Activities – “Advanced Landing Systems” – WP4.1

a. Background

The preparation of technologies for the future more electrical aircraft is considered by SAFRAN as the current highest priority for Research and Technology programmes on landing gears. More electrical technologies offer the possibility to improve performance in flight by reducing the total weight of the aircraft and also to develop new capabilities for on-ground operations such as autonomous taxiing. Additional advantages of electrical technologies are also expected on maintenance and dispatch of aircraft.

However, the more electrical technologies offer higher benefits to the airlines on short-medium range aircraft than on long range aircraft; this is why the first generation of more electrical aircraft is focusing on short-medium range aircraft with high rotation rates per day, emphasizing the need for improved efficiency on ground through various techniques; autonomous green taxiing for fuel savings and dispatch vs allocated slots; reduction of Turn Around Time (TAT) in order to help increasing the number of rotations per day.

First of all, it has to be reminded that main landing gears retraction is one of the sizing consumers for aircraft centralized hydraulic power generation whereas it is a relatively low power consumer compared to aircraft electrical power capabilities. Developing a weight effective and robust solution to perform this function with electrical power is considered as being one of the enabler for complete removal of aircraft centralized hydraulic power generation and more efficient management of aircraft power sources.

Main landing gears are also highly integrated, carrying braking systems and additional cooling devices and considered as the optimal location for implementing new electrical autonomous taxiing systems. The target of a “full electrical main landing gear” is considered achievable in the short medium term horizon covering extension retraction, up-lock, electrical braking actuation, and electrical autonomous taxiing; all these functions needing a high level of integration and commonality of technologies.

For all these reasons, SAFRAN has participated recently to several R&T programs all focused on the development of electrical actuation technologies: EU Actuation 2015, UK-ELGEAR, Fr-ISS Power & Control. These programmes have permitted to build a robust background in various areas:

- Electro Hydrostatic Actuator (EHA) and Electromechanical Actuator (EMA) technologies
- EHA pumps technology to cover 150,000 flight hours life duration
- Standardisation of electrical modules to decrease electrical actuators costs and improve reliability
- Main Landing Gear Extension / Retraction system models
- Full functional EHA demonstration for medium power Extension / Retraction (Nose Landing Gear)
In addition, Safran is also participating to the Work Package WP3.7 of Clean Sky SGO – Smart Operations on Ground with the objective of demonstrating the performance of this first concept of autonomous taxiing system.

All these completed and on-going studies have globally confirmed the relevance of the objective of full electrical main landing gear but have also highlighted several technical difficulties, mainly linked to the balance weight-performance-reliability that will need further work.

b. High level objectives at demonstrator / technology levels

Based on the conclusions of these previous demonstrations, SAFRAN propose to address, within Clean Sky 2 framework, three major challenges focused on Full Electrical Main Landing Gears:

- Mature a full electrical landing system for main gear, covering extension, retraction, door actuation and electrical braking
- Mature a second generation of green autonomous taxiing system
- Demonstrate a short Turn Around Time (TAT) braking system – Wheel, Brake, and Cooling fan

- Full Electrical Actuation System for Main Landing Gears

SAFRAN propose to mature a full electrical actuation system for the next generation of aircraft, targeting the maturity level TRL 6 for the complete extension retraction system, comprising Main Landing Gear (MLG) extension retraction actuator, MLG Unlock actuator, MLG door actuator, MLG and doors uplocks, electrical braking actuation.

Both electro-hydrostatic and electro mechanical actuation will be assessed and compared in terms of weight, reliability and safety and the physical demonstration will be performed on the most efficient configuration: the first step of this work package will be to perform a trade-off study on the landing gear actuation system architecture and to define the most efficient actuators technology for each application: EHA, Distributed EHA, EMA… Then, based on this choice, a full electrical system will be designed, manufactured and tested at actuator level in a representative environment and on an existing single aisle aircraft main landing gear.

- Second generation of Green Autonomous Taxiing System

SAFRAN have developed a first generation of green autonomous taxiing systems for single aisle aircraft. These systems are fitted to existing aircraft main landing gears and show a high benefit in terms of fuel savings. The design constraints for this first generation based on available technologies lead to relatively important modifications of the wheels and brakes configurations and could be further optimized by improvements of the technology bricks and a better global integration in a full electrical system design. Moreover, additional energy savings could be obtained by implementing new functions on the current autonomous taxiing system. SAFRAN have concurrently started working within Clean Sky 1 framework on some of the technology bricks for the next generation such as Direct Drive Motors or Power Electronic with Energy Recycling System.
- **Second Generation Architecture Studies:**

In a first stage, the lessons learnt so far on Generation 1 and on *Clean Sky* 1 studies will be drawn and baseline architecture for the next generation will be established. These architecture studies will address the possibility of energy recycling, optimization and storage for the local power network. The architecture of the green taxiing systems will also be revisited in order to increase its modularity for reduction of non-recurring and recurring costs and for potential usage on different types of aircraft such as single aisle, regional and business jets.

- **Second Generation Demonstrator Detailed Design**

The chosen architecture will be the starting point for the detailed design of components. Particular attention will be paid to new functions such as energy recycling or to key components such as electric motors, wheel actuators and power electronics.

- **Manufacturing and Tests**

The whole demonstration system will be manufactured and tested in a representative environment to demonstrate the achievement of the TRL5 maturity level, including functional and performance testing for the complete operational duty cycles; environmental testing: thermal, vibration and environmental humidity/altitude.

- **Short Turn Around Time Braking System**

After braking at landing and taxi in, it is necessary to cool the A/C wheels and brakes to ensure safe operations for taxi out and take-off. This cooling time is referred to as the Turn-Around-Time and is a significant operational performance parameter of the braking system. The maximum allowed temperature before take-off driving the TAT is defined so that there is no risk of hydraulic fluid inflammation in case of leakage and that metallic structures and tires remain in the authorized range of operations. The graphs below show the tire/wheel/brake assembly temperatures after a maximum energy braking in the authorized range for nominal operations.

The current state of the art for short medium range aircraft for TAT is higher than 45 minutes for uncooled configuration and close to 30 minutes for cooled configuration using a specific Brake Cooling Fan (BCF).

SAFRAN propose to develop and demonstrate the short TAT operations braking system, as part of the *Clean Sky* 2 Programme, from TRL 3 to TRL 6 maturity level by the end 2020. The targeted performances are the following:

- TAT reduced from 45 down to 30 minutes, without forced convection
- TAT reduced from 30 down to 15 minutes, with forced convection.
These research activities will be conducted considering that the wheel and brake equipment is fitted with an electrical taxiing system, which induces additional design constraints compared to current configurations. The forced convection system improvement also seeks for more integrated BCF. Indeed, optimization of the wheel and brake aerodynamics enables to take higher advantage of the BCF-induced air flow. Thus, the new BCF flow rate requirements will allow design optimizations for additional noise reduction on ground.

c. Description of added value of the demo / techno vs. state of the art

- **Full Electrical Actuation System for Main Landing Gears**

  State of the art is based on hydraulic actuation with central hydraulic power. The EHA actuation system will be powered by decentralized hydraulic power generation allowing global aircraft weight savings.

  **Added value compared to the state of the art:**
  - Safety: at least equal
  - Reliability: increased
  - System weight reduction: 25% compared to state of the Electrical Main Landing Gear actuation
  - Global aircraft weight reduction; enabler for overall weight reduction estimated at about 500 kg for a short medium range aircraft

- **Second generation of Green Autonomous Taxiing System**

  The first generation of green taxiing systems is currently being offered to the market, based on existing technologies and fitted to existing aircraft.

  **Added value compared to the state of the art:**
  - Contribution to global aircraft weight reduction by improvement of performance of the components
  - Energy consumption: energy recycling during taxiing phase

- **Short Turn Around Time Braking System**

  The current available systems offer possibility to decrease TAT to about 30 minutes, with forced convection, the objective is to decrease the TAT to 30 minutes without BCF and to 15 minutes with BCF.

  **Added value compared to the state of the art:**
  - Enhanced mobility: enabler for increased rotations per day and increased dispatch
  - Global aircraft weight reduction: reduction by removal of brake cooling fan or little contribution by improving the efficiency and weight of the components
  - Energy consumption: reduction either via removal of brake cooling fan or by increased efficiency of brake cooling fan

d. High level plan with schedule, major milestones, deliverables, TRL to target
### Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD

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<tr>
<th>Advanced Landing Systems</th>
<th>TECHNOLOGIES</th>
<th>SYSTEMS ITD</th>
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<td>Technology bricks improvement</td>
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<td>Detailed design of demonstrator</td>
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<td>Manufacturing and demonstration tests</td>
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<td>TRL 6 maturity validation</td>
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<tr>
<td>2nd generation of Autonomous taxiing</td>
<td>Specifications of enhanced system</td>
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### Advanced Landing Systems

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<th>Activity</th>
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<td>Detailed design of demonstrator</td>
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<td>Manufacturing and demonstration tests</td>
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<td>TRL 5 maturity validation</td>
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### Short TAT braking system

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<tr>
<th>Activity</th>
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<tr>
<td>Short TAT system requirement</td>
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<td>Concept studies</td>
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<tr>
<td>Enhanced brake cooling fan design</td>
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<td>Manufacturing and demonstration tests</td>
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<td>TRL 6 maturity validation</td>
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In order to ensure compliant activities related to 2nd generation of Autonomous Taxiing and SESAR, dedicated WP 0.X will be managed at Systems ITD level. Moreover, SESAR guidelines which could influence ground traffic management will be taken into account in the requirements stage of the Green Taxiing and Short TAT WPs.

**f. Expected high level added value per demo / techno wrt. H2020 objectives**

- **Environmental**: Reduction of emissions on ground, contribution of aircraft weight reduction through the development of electrical actuation and contribution to aircraft noise reduction for the final stage of the flight.
- **Competitiveness**: Reduction of operating cost through fuel savings on ground and in flight, products life extension through health and usage monitoring, reduced maintenance through development of electrical actuation.
- **Societal**: Contribution to noise reduction in-flight and on-ground, reduced Turn Around Time enabling increase of rotations per day.
II. **Nose Landing Gears Activities - Electrical NLG System Demonstrator**

a. **Background**

On most aircrafts the nose landing gear is the only hydraulic power consumer installed in the forward fuselage section. The nose landing gear requires hydraulic ports for extension/ retraction and steering. Since these two functions need to be independent of each other, two pressure lines and one return line have to be routed all along the fuselage. Particular for large aircrafts, these lines means significantly more weight and more cost. Further, in case of a leak the hydraulic lines constitute a serious hazard. For these reasons, it is logical to replace the hydraulic power by electric one -which is already available for the nose cone consumers – in order to manage the nose landing gear power demand.

Apart from these information, aircraft manufacturer have the ambition for a more electric aircraft. In recognition of the above stated facts, LIEBHERR pursue the clear aim for the next aircraft generation to develop and provide a Nose Landing Gear which interfaces with the electrical power supply only.

In the recent past, studies to support more electric aircraft solutions already have been performed on a decentralised hydraulic power system, which was accomplished within the European Project “Power Optimized Aircraft (POA)” as well as full electrical Nose Landing Gear Actuation in the European Project “Power Optimized Aircraft (POA)” and in the German national funded R&T Program “LuFo”.[NH(C)45]

The main objectives were:
- Nose Landing Gear actuation and Nose Wheel Steering using EHA (Electro-Hydrostatic Actuator) technology. The outcome is:
  - New architectures for hydraulic valves
  - Hydraulic valve light weight constructions
  - Full functional EHA demonstrator hardware
  - Analytical study of a high integrated optimised EHA package

b. **Clean Sky 2 High-level objectives**

Based on the lessons learnt of a.m. projects, LIEBHERR propose within *Clean Sky 2* to design and test new Nose Landing Gear System configurations deploying EHA and EMA technologies. These configurations will be traded in terms of weight, safety and reliability.

- **EHA for Nose Landing Gear Actuation and Nose Wheel Steering System**

  The aim is to demonstrate a high integrated EHA System package for a single aile aircraft Nose Landing Gear powered by A/C electrical power system. In this context, LIEBHERR envisage to reach TRL6, which is an equivalent term for flight readiness.

  The LIEBHERR proposal feature an extension / retraction system and a steering system composed of:
  - decentralized EHA aggregate
  - actuators for steering
  - unlock actuator
  - retraction actuator
  - power controller with control / monitor architecture for closed loop control.
In addition, the system provides an independent electro-hydraulic actuator for release of the up and locked position in case of a normal extension failure. Locking in both, extended and retracted conditions is attained using the lock link mechanism (no additional up lock required).

There is a risk that the forward nose gear doors cannot be slaved to the gear due to load and/or kinematic constraints. To safeguard the gear actuation and steering EHA system concepts, a separate, sequenced door actuation is required encompassing a dedicated doorlock unit, which features two EMA for normal and for alternate door release. Door actuation will be performed by a hydraulic door actuator controlled by the baseline Power Pack Controller.

The basic features of the system will be:
- Alone standing Power Pack Controller
- EHA subsystem for gear actuation and nose wheel steering consisting of:
  - Alternate EHA subsystem
  - EMA door lock
  - Control valves
  - Accumulators
  - Various sensors

**c. Description of added value of the demo / techno vs. state of the art**

- **EHA Nose Landing Gear System**
  
  State of the art Landing Gear actuation system for short and medium range aircraft powered by central hydraulic power source. With the de-centralised system, the aircraft generation with centralized hydraulic power package will be replaced by decentralized hydraulic power generation which provides promising benefits such as:
  
  - Less complex control valves and actuators due to performed closed loop control circuit for the motor control electronic gear actuation
  - Reduction of weight and cost on aircraft level due to the deployment of the same motor control electronic for gear actuation and nose wheel steering
  - No Centralised A/C hydraulic needed

**Added value compared to the state of the art:**

- Safety: at least equal
- Reliability: better thanks to less complex control valves (dynamic seals)
- Optimized Energy consumption: -10 to -20%
- Global A/C Weight: enabler for overall aircraft weight reduction (to be evaluated on A/C level)
d. High-level plan with schedule, major milestones, deliverables, TRL to target

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<tr>
<td>Decentralised EHA Nose Landing Gear System</td>
<td>Demonstrator</td>
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<td>EHA for Steering and R/E + Power Pack</td>
<td>TRL 3</td>
<td>TRL 4</td>
<td>TRL 5</td>
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<td></td>
<td>Autonomous Alternate EHA for emerg. Release</td>
<td>TRL 3</td>
<td>TRL 4</td>
<td>TRL 5</td>
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<td></td>
<td>Power Pack Control</td>
<td>TRL 3</td>
<td>TRL 4</td>
<td>TRL 5</td>
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e. Interaction and interfaces with other ITDs / IADPs / TE / ECO and within ITD Systems

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<th>Decentralised EHA Landing Gear</th>
<th>ITD Systems</th>
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<td>Airbus Participation</td>
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<td>NLG Power supply concept</td>
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<td>NLG electrical steering and actuation</td>
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<td>NLG weight and cost optimization</td>
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III. **Tiltrotor/Rotorcraft Landing Gears Activities - Electrical Landing Gear System Demonstrator**

**a. Background**

One of the main major changes to be implemented in the next generation of aircraft is a more electrical architecture. This challenge impacts the actuation of the landing gear system, and enables breakthrough technologies to be developed. On the Tiltrotor/ Rotorcraft platform, the introduction of electro-mechanical technology for landing gear actuation functions promises benefits in terms of reliability, total aircraft weight and life cycle cost. In addition an active shock absorber device for Tiltrotor/ Rotorcraft provides further potentials to optimize performance and consequently reduces weight.

With this regards, LIEBHERR is planning to develop a full electrical landing gear system for Tiltrotor/ Rotorcraft, challenging the existing actuation and shock absorber concepts.

In order to support the full electric aircraft approach, studies have been carried out by LIEBHERR for EMA (Electro-Mechanical Actuator) technology in the past. These studies focused on Nose Landing Gear actuation and Nose Wheel Steering functions using rotary EMA actuation. These R&D projects were supported by European Project “Power Optimized Aircraft (POA)” and the German national funded R&D Program “LuFo”.

The main objectives have been:

- Nose Landing Gear actuation and Nose Wheel Steering using EMA (Electro-Mechanical Actuator) technology:
  - Rotary EMA for Retraction/Extension and for Steering
  - EMA Uplock
  - Functional EMA demonstrators for component testing
  - High-/Low Temperature Testing

The evaluation of these developed large aircraft landing gear EMA actuators result in higher weights caused by challenging safety and reliability requirements and therefore they are not competitive today.

As a consequence, LLI’s focus is now on Tiltrotor/ Rotorcraft.

**b. Clean Sky 2 High-level objectives**

Taking into account the emerging challenges of the more electrical aircraft, LIEBHERR proposes to tackle the technological challenges related to a hydraulic-free landing gear actuation system and landing gear shock absorbers for a Tiltrotor/ Rotorcraft platform. The main objective is to demonstrate EMA application to the landing gear system. The following functions resp. components will be developed.

- Landing Gear System incl. Structure:
  - Active Shock Absorbers
  - EMA for Retraction/ Extension
  - EMA for Steering
  - EMA for Braking
  - EMA for autonomous Taxiing
  - Signal and Power electronics
  - Cockpit Controls

The first project phase will focus on Requirement Capture and Trading different EMA concepts in terms of functionality, performance, weight and costs. The main focus during System and Equipment development will
be on the EMA actuators. Different new technologies for jam tolerant actuators and light weight clutch/gears/motor concepts including health monitoring will be investigated. The most promising solution will then be detailed and a prototype demonstration on Subsystem and System Level will be provided. Additionally, the Power Management on Tiltrotor/Rotorcraft Level will investigated jointly with Tiltrotor/Rotorcraft manufacturer and the resulting Control Architecture and Power distribution will be part of the demonstration.

The demonstration on Subsystem and System Level, will be developed up to TRL 6 and continued by flight test campaign.

c. Description of added value of the demo / techno vs. state of the art

EMA Nose Landing Gear Systems studied by Liebherr are not competitive for fixed wing aircraft, but there is more potential expected for Tiltrotor/Rotorcraft. Main problem is the increased system weight driven by complex EMA actuators and the additional electrical power stages. However, there is good potential for optimising the systems by using alternative actuator technologies and optimised power supply architectures. Moreover, a critical review of today’s requirements can lead to lower complexity and lighter weight systems. If this can be achieved, the following advantages arise when using EMA technology compared to a Hydraulic- or EHA System:

Added value compared to the state of the art:

- Safety: No impact
- Reliability: Improved reliability due to replacement of a complete hydraulic circuit
- Maintainability: Reduced activities and reduced cost
- Environmental: Reduced environmental impact through elimination of hydraulic leakage
- Weight: Weight reduction on Tiltrotor/Rotorcraft Level

Active shock absorber device will provide adaptive response to different operating conditions and hence will reduce the fatigue loads and landing gear weight.

d. High-level plan with schedule, major milestones, deliverables, TRL to target

<table>
<thead>
<tr>
<th>Road Map Landing Gear</th>
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<tbody>
<tr>
<td>Electrical Rotorcraft Landing Gear System</td>
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e. Interaction and interfaces with other ITDs / IADPs / TE / ECO and within ITD Systems
<table>
<thead>
<tr>
<th>Electrical Tiltrotor/ Rotorcraft Landing Gear System</th>
<th>Systems ITD</th>
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<td>Electrical actuated landing gear Extension/ Retraction</td>
<td>Requirements capture and baseline definition</td>
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<td>System development</td>
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<td>Components development</td>
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<tr>
<td>Electrical actuated Nose Wheel Steering</td>
<td>Components production, verification and test</td>
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<td>System verification and test</td>
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<td>Flight test demonstration</td>
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<td>Electric Brakes</td>
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<td>Active Shock Absorber</td>
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<td>Components production, verification and test</td>
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<td>System verification and test</td>
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<td>Flight test demonstration</td>
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11.6.5 Electrical Chain – WP5

I. Work breakdown Structure (WBS)

In *Clean Sky 2*, the WPS covers the electrical chain and the activities are included into two main domains. First domain integrates the sources of electrical network with Main, APU and dedicated generation and adaptive electrical conversion with a link through energy storage. Second domain integrates the energy management with innovative electrical network and power management center, both sub work-packages are link with strategy power management to evaluate the management laws which could be defined with the collaborators.
II. Non Propulsive Energy Generation

a. Next Generation Main and APU Standalone Electrical Power Generation

Note: This paragraph is about the activities of the electrical machine and the starter function. Although another dedicated paragraph, addressed after this one, relates more specifically the activities on the Generator Control Unit, details related to GCU activities are already inserted in this paragraph. Both activities are dealt with simultaneously because of many synergies between them. This presentation in both separated paragraphs was written for readability issues.

Background – Clean Sky activities

In the frame of Clean Sky, the following investigations have been performed and these results will be the technical foundation for Clean Sky 2 project. Moreover the indicated TRL milestone will be the starting point for the beginning of Clean Sky 2 project in 2015:

- Optimisation of a 200 kVA oil cooled starter generator demonstrator for 230VAC power network, TRL3 was reached for this AC generator.
- TRL4 oil cooled starter generator demonstrator for 115VAC network passed during the year 2013,
- Optimization of an air cooled starter generator demonstrator coupled with a rectifier unit and regulating with a full digital control unit (GCU) on the DC voltage power network. TRL4 passed for the generator during the year 2013 and TRL3/4 will be reached for the control unit depending on the functions at least for the middle of 2015.
- Study of an oil cooled main starter generator for power HVDC network and TRL3 was reached during the year 2013

The next challenges for Clean Sky 2 relate to the following tasks:

- Develop further the investigations related to new aircraft AC and DC power networks;
- Integrate digital control in the Starter Box Unit (SBU) to control the starter-generators (S/G) and to optimize the interaction between the SBU and the S/G; Implement innovative control strategies (torque, speed, combined torque/speed);
- Optimize Electrical Start Function using two S/Gs in parallel on the same engine;
Clean Sky 2 Joint Technology Initiative in Aeronautics

- Integrate new technology bricks to increase the power density;
- Develop Health Monitoring and analyse for preventive maintenance and simplify operations to optimize ownership total cost (integration of sensors for bearings and oil circuit).

**o High level objectives at demonstrator / technology levels**

The major objective of “Main and APU Generation” project is to actively prepare the ATA24 System for the future generation of aircraft power network. The activities will address the following tasks:

- For future HVDC network, mature the starter generator and confirm the reduction of weight
- For AC network, continue to improve the three-stage synchronous machine with optimization of multi physical modelling and simulation
- Study the parallelism of several DC generators to control and to manage electrical network, power distribution, availability of electrical power and faulty generator isolation
- Increase the power density and the efficiency of the machine by integrating technology bricks:
  - winding compliant with high voltage constraints and with low filtering rectification
  - adapted electromagnetic design able to cope with high speed stress
- For both types of network: develop health monitoring system for ATA24 enabling extension of Mean Time Between Maintenance (MTBM) (select or develop sensors, integrate concept of diagnostic and prognostic to be implemented in the GCU )

The targets at the end of this project are to have electrical generation equipment, validated and integrated on specific aircraft network and for both families of starter-generators (for DC and AC network).

**o Description of added value of the demo / techno vs. state of the art**

Through this demonstrator, processes and technologies will be evaluated and challenged to usual solutions, the impact on all System could be observed during development or operational use. For these tasks, transverse works will also be necessary like research of material property, but all so simulation and V&V tools, incremental certification, etc.

**Added value compared to the state of the art for AC network**

Based on the results from previous projects such as MOET, MEGEVE, GETI, and *Clean Sky 1, Clean Sky 2* will develop equipment, systems and solutions for more electrical aircraft configurations. Through these previous R&T projects, results have consolidated the interest of the three stage electrical machine which is the reference design for power electrical generator in terms of safety analysis for aircraft architecture, but also in terms of technical impacts (weight, volume, control, maintainability and integration facilities in aircraft architecture). Furthermore targets are to pursue these works with higher integration level and particularly to add dedicated functions such as the electrical starter for APU and MAIN engine.
The activities concerning electrical starter will also consist of:

- Optimizing the power electronic hardware and the exciter part of the generator,
- Implementing innovative control laws to start two electrical starter generators on the same engine,
- Initiating sensorless start control.

**Added value compared to the state of the art HVDC network**

Main targets are to contribute to the main following objectives:

- **Reduction of aircraft weight**: Mass reduction of 30% is estimated for the next generation of HVCD generator; gains are expected mainly through higher speed but also through the supply of the HVDC electrical network without frequencies constraints; overload reduction induced by generator paralleling is also contributor to mass reduction. Innovative rotor design suitable to high centrifugal forces will be developed, but also adapted oil cooling system to reduce losses induced by this high speed will be integrated in the demonstrators. Also this reduction of mass will be analysed to confirm the more significant gain for constant speed APU generator.

- **Challenge key indicators like power density and life cycle cost**

The following improvements allow increasing power density and reducing life cycle cost of the next generation of electrical starter generator for APU and MAIN engine:
- Develop robust pieces able to cope with high temperature constraints.
- For generator using oil cooling system, hydraulic pump should be designed to be more robust and efficient. Further the circulation of the cooling liquid will be studied to ensure uniform lubrication of the bearing for high speed motor design
- Health and usage monitoring functions contribute to extend the products life and to reduce maintenance
- Propose dedicated control laws to evaluate sensorless start control for APU and MAIN engine

Reduction of fuel consumption and CO$_2$ emissions in all flight phases: the weight reduction is the significant contribution for this product line to these objectives.
Main and APU generation activities in *Clean Sky 2* will focus on high TRL 5 to test new technologies and concepts in representative environment.

For each TRL level the following tasks are foreseen:

- Development and design will be processed through usual milestones of work reviews: specification review, preliminary design review (PDR), critical design review (CDR), test plan review and TRL assessment review.
- Equipment realization, the number of equipment will be depending on TRL level; information given for reference only, quantity could be modified depending on the interest of the IADP airframers:
  - For TRL 4, one mock-up to evaluate and to choose the technological bricks in laboratory environment,
  - For TRL 5, one prototype to be evaluated in a representative environment,
  - For TRL 6, TRL 5 prototype with adapted interfaces to be integrated in a complete system with representative environment (tests on Iron Bird or flight tests).
Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD

<table>
<thead>
<tr>
<th>Operational WPs</th>
<th>Inputs/Outputs in ITD Systems</th>
<th>Inputs from other ITD/IADP</th>
<th>Output to other ITD/IADP</th>
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<tbody>
<tr>
<td>WP5.1.1</td>
<td>For AC and DC network equipment, the following activities are expected :</td>
<td>- LPA AIDP, RA IADP and Rotor craft (FR IADP):Network specifications - electrical and mechanical interfaces specifications - Test plan contribution for evaluation - participation TRL Assessment reviews</td>
<td>Demonstration equipment for IADP test bench. Demonstrator deliveries : - LPA IADP ( link with Plateforme 2 –WP0) : VFSG for HVDC network , and generator for AC network - RA IADP ( link with WP2.3 energy optimized RA and link with WP2.3.4 advanced EPGDS ) : VFSG for AC network , full digital GCU, - FR IADP (link with WP8 Electrical system : generator demonstrator with full digital GCU - SAT (link with EPGDS): starter generator - ECO : evaluation</td>
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<td>• WP 6.1 for interaction with E-ECS</td>
<td>ECO : material and processes and evaluation</td>
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<td>• WP 5.2 for interaction with modular centralized power bay.</td>
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<td>• WP6.4 : test facilities GETI and PROVEN</td>
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<td>• WP5.1.2 : specification with power conversion</td>
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Expected high level added value per demo / techno wrt. H2020 objectives

- **Environmental**: Fuel consumption reduction will be :
  - weight savings with higher power density electrical power generator,

- **Competitiveness**: product life by improving reparability and maintainability capabilities, and increase electrical power generator availability through integration of health monitoring functions.

- **Societal**: Proposed developments and collaborations will open opportunities for research and future business for the European supply chain and Academia.
b. DGCU for electrical S/G for main and APU applications

o Background – Clean Sky activities

In the frame of Clean Sky, the following investigation took place:

- Development of a full digital control unit for variable frequencies starter generator (VFSG) connected through a rectifier unit to establish a DC power network. For this application, the DC voltage level was used as point of regulation. The TRL 3/4 maturity levels will be reached at least for the middle of the year 2015, these milestones will be depending on the implemented functions and a table in the next paragraph presents the expected starting point of these maturity levels for the beginning of the Clean Sky 2 project.

![Digital control unit view](image)

Added value compared to the state of the art:

The next challenges for Clean Sky 2 it is envisaged to perform the following tasks:

- Develop further those full digital control and extend its application for electrical generator for future aircraft network (HVDC network) and also AC networks (115VAC and 230VAC). Today marketed generator control units are designed with analog electronics, digital control will bring facilities to implement innovative control law and to adapt on different type of power network
- Develop architecture for dedicated network to increase the reliability and availability of power network with the implementation of health monitoring functions.
- Analyse the impact of innovative control laws on the electrical machine architecture, with the possibility to optimize the size of machine parts with dedicated control laws and specific protections,
- Improved performance for network faults as transient operation, overload and short-circuit.

o High-level objectives at demonstrator / technology levels

Mainly the integration of full digital control should allow the integration of new functionalities, as indicated below:

- Flexibility with the full digital regulation and command
- Monitoring and analyse for preventive maintenance
- Protection, fault isolation
○ **Description of added value of the demo / techno vs. state of the art**

Through this demonstrator, processes and technologies will be evaluated and challenged to usual solutions, the impact on all System could be observed during development or operational use. For these tasks, transverse works will also be necessary like research of programmable component, but also simulation, V&V tools, and incremental certification, etc.

○ **High-level plan with schedule, major milestones, deliverables, TRL to target**

Full digital Main and APU control units activities in *Clean Sky 2* will focus on high TRL 5 to test new technologies and concepts in representative environment as presented in the bellow schedule:

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<tbody>
<tr>
<td>Control unit</td>
<td>Model</td>
<td>GCU for DC VF S/G</td>
<td>TRL 4</td>
<td>TRL 5</td>
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<tr>
<td>Digital control loop</td>
<td>Modelling and Integration</td>
<td>GCU for AC VF S/G</td>
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<tr>
<td>Health monitoring</td>
<td>State of art, Simulation, Experimental tests, Integration algorithm</td>
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For each TRL level the following tasks are foreseen:

- Development and conception will be progressed through usual milestones of work reviews: specification review, preliminary design review (PDR), conception design review (CDR), test plan review and TRL assessment review
- Equipment realization, the number of equipment will be depending on TRL level. Information given for reference only, quantity could be modified depending on the interest of the IADP airframers:
  - for TRL 3, evaluation of function through sensor performance tests
  - for TRL 4, two mock-ups to evaluate and to choose the technological bricks in laboratory environment,
  - for TRL 5, three prototypes to be evaluated in a representative environment, Quantity could be adapted following the interest of IADP airframers,
  - for TRL 6, two TRL 5 prototypes with adapted interfaces to be integrated in a complete system with representative environment (tests on Iron Bird or flight tests).
○ Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD

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<tr>
<th>Operational WPs</th>
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<tr>
<td>WP5.1.1</td>
<td>For AC and DC network equipment, the following activities are expected WP 6.1 for interaction with E-ECS WP 5.2.2 for interaction with modular centralized power bay WP6.4. : test facilities GETI and PROVEN WP6.3 : major load WP5.1.3 : specification with power conversion</td>
<td>LPA AIDP, RA IADP and Rotor craft (FR IADP): - Network specifications - electrical and mechanical interfaces - Test plan contribution for evaluation - participation TRL Assessment reviews ECO : material and processes</td>
<td>Demonstration equipment for IADP test bench. Demonstrator deliveries: LPA IADP (link with Plateforme 2 – WP0): full digital GCU for HVDC network. RA IADP (link with WP2.3 energy optimized RA and link with WP2.3.4 advanced EPGDS): full digital GCU for AC network FR IADP (link with WP8 Electrical System: full digital GCU for DC network ECO: DC network ECO: evaluation</td>
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</table>

○ Expected high level added value per demo / techno wrt. H2020 objectives

The expected benefit from this project is to propose a modular control box for starter generator, with integrated health monitoring to simplified maintenance.

- **Environmental**: Fuel consumption reduction will be:
  - electrical power generator accepting higher charge rates of power consumption,
  - flexibilities to manage electrical consumption

- **Competitiveness**: Reduction of operative costs through fuel saving in flight mode with accepting higher charge rates and flexibilities to manage electrical consumption, product life by improving reparability and maintainability capabilities, and increase electrical power generator availability through integration of health monitoring functions and sensor less control laws

- **Societal**: Proposed developments and collaborations will open opportunities for research and future business for the European supply chain and Academia.
c. **Dedicated Electrical Power Generation and Motors For Emergency Flight Operations**

**Background – *Clean Sky* activities**

This Activity was not developed in *Clean Sky*, but new opportunities appeared recently to take advantage of high power density electrical machines in applications where the machine operates in motoring mode during less than one minute and in generating mode permanently. The expected power range is 50 – 150 kW in motoring mode and only several KW in generating mode. In this project, the targets are to progress on the compactness of electrical machines and also to make this motor compatible with an electrical generating mode in normal flight conditions. TRL3 will be the initial maturity level of this type of motor. This milestone was reached in 2012 through a specific R&T project.

**High level objectives at demonstrator / technology levels**

The major objective of “Motors for emergency flight operations” project is to mature the concept by developing a demonstrator which complies with A/C or rotorcraft environmental conditions. The concept will also scope with the A/C architecture, in the aim to achieve safety goals and A/C certification. The activities will address these following tasks:
- Increase the maturity level of high speed motors;
- Develop electrical behavioural model and multi-physical simulation;
- Use new topologies of stator and rotor (windings, permanent magnets);
- Introduce high temperature material to reduce the motor weight;
- Analyse consequences of high speed rotation on rotor mechanical structure and cooling system;
- Adapt Electrical Power Module (PEM) and Control Unit to the high speed motor, by using the results of the studies conducted on PEMs;
- Study, simulate and test control laws for this type of machine.

**Description of added value of the demo / techno vs. state of the art**

The added value of the demonstrator is to validate high integrated electrical motor. The demonstrator will be an opportunity to develop industrial processes of this type of electrical motor to mitigate potential risks. During the development phase novel machine-drive topologies will be evaluated. For instance a flux-switching machine will be studied. It presents the advantages of both Switch Reluctance Machine and Permanent Magnet Machine.
High-level plan with schedule, major milestones, deliverables, TRL to target

Motors for emergency flight activities in Clean Sky 2 will focus on high TRL 4 to test new technologies and concepts in a representative environment.

For each TRL level the following tasks are foreseen:

- Development and conception will progress through usual milestones of work reviews: specification review, preliminary design review (PDR), conception design review (CDR), test plan review, and TRL assessment review.
- Equipment realizations depending on TRL level:
  - For TRL 4, one mock-up to evaluate and choose the technological bricks in laboratory environment,
  - For TRL 5, one prototype to be tested in a representative environment,
  - For TRL 6, one TRL 5 prototype with modified interfaces to be integrated in a complete system and a representative environment (tests on Iron Bird or flight tests).

Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD

Expected high level added value per demo / techno wrt. H2020 objectives
The following benefits are expected from this project:

- High reliability for emergency flight conditions
- New operative modes on ground and in flight

- **Environmental**: Fuel consumption reduction will be achieved through:
  - Weight saving with higher power density electrical power motor;
  - Mutualisation of motor and generator modes at different flight phases.

- **Competitiveness**:
  - Reduction of operative costs through mutualisation electrical needs, generator in steady flight condition and motor in emergency condition.
  - Product life by improving reparability and maintainability capabilities with robustness electrical machine.

- **Societal**: Proposed developments and collaborations will open opportunities for research and future business for the European supply chain (automotive industry) and Academia.
III. **Power Distribution**

a. **Innovative Electrical Network (IEN)**

   - **Background – Clean Sky activities**

   In the frame of *Clean Sky* following investigations have taken place:
   - Tools and methodologies to optimize wiring taking into account the new constraints due to More Electrical Aircraft (MEA) & More Composite Aircraft (MCA)
   - EWIS HV and EMC optimized prototype for MEA and MCA consistent with new regulations
   - EWIS Design guide
   - Electrical generation, conversion and power distribution,
   - ATA24-level integration testing for Green Turboprop, Green Rotorcraft and Green Business Jet on the COPPER BIRD platform.

   In addition other national or European programmes have also yielded advanced concepts and prototypes which are relevant to develop this “Innovative Electrical Network” demonstrator:
   - In GENOME; tools to support EWIS design are developed, and distribution centers mutualising energy are designed.
   - In CORAC, Electrical structural network are studied to improve knowledge, propose optimization strategy and health monitoring strategy.
   - HARNESS BITE studies EWIS health monitoring, and some national projects (SAHARA) are launched on data communication.

   During previous projects, it has already been developed:

   - primary distribution based on power electronic
   - modular secondary distribution
   - racking
   - Power line protection and control
   - transformers, Inverter and filtering
   - Overall integration challenges such as heat dissipation and thermal sizing.
   - Wiring health monitoring
   - Power line communication
   - etc.
- **High-level objectives at demonstrator / technology levels**

The MEA trend leads to replace hydraulic and pneumatic loads by electrical loads. This implies an increasing power embedded on board: more loads, more sources, will be located in the aircraft. These different components will need to be connected together through the distribution network, complying with safety requirements and operational need (complexity and weight mastered, reliability still increased etc)

The more electric aircraft will require rethinking of electricity distribution concepts on board to take into account these significant changes. The distribution network will be a main brick to reach MEA objectives. MEA will request to design this network integrated, as a whole, and not only de-correlated from load and sources number, position, technologies...

The current power distribution architecture of all current aircraft is based on a star network concept or tree network concept since introduction of secondary electrical power distribution centre. Current distribution topologies may reach their limit in term of optimization, and if kept as today, they will dramatically increase the need for EWIS components to interconnect all loads and sources. New topologies are possible and could lead to important gains in the more electrical aircraft context.

Such implementation will be strongly supported and exploited in the COPPER BIRD ® electrical system rig.

The main objectives for this WP in Cleansky 2 is to study innovative network with airframers on defined use cases and after analyses to propose, design, manufacture and test enablers for different distribution geometries. At the end of Cleansky 2, those technological bricks will be associated to demonstrate the global network feasibility. They will be ready for program introduction and development.

**Goals are:**
- To have a trans ATA 92/24 approach to optimize overall design of the electrical system components including EWIS, distribution and conversion and other network component for a global gain at aircraft level
- To balance constraints of high dispatch reliability with high-gap technology with no prior in-service experience.
- To demonstrate highly integrated, weight-optimized power conversion and distribution functions, in a modular, generic and highly re-usable architecture.
- To develop advance critical EWIS technology to be applied on MEA and MCA and take into account new EWIS constraints (components, Communication, Health monitoring, protection...)
- To simplify the installation
- To master complexity and costs

This project proposes to develop a highly decentralized and flexible innovative power Electrical demonstrator being able to:
- Relieve or "reconfigure" itself by switching in case of overload or failures
- Mutualise distribution parts between different loads and sources
- Assess its health in real time
- Protect dynamically load wiring and components
- Mix data and power on the same EWIS architecture

After work with airframer and some core partners, requirements will be established taking into account different domain:
- Requirements relative to aircraft need, load and source data, topology foreseen, operation requirement.
- Other requirements concerning the regulations, the manufacturing and installation costs objectives (for design to cost to target A/C program where costs are the main driver). Safety is a main driver as it could be a showstopper for many architectures, it will be deeply studied in airworthiness workpackage. Among them, we will find the weight, cost and space/volume objectives, the consumption diminution, the MTBF, the network availability targeted. Requirements concerning operation will be added in this WP.

Those set of requirements will be established in cooperation and will be the core specification of IEN. Depending on the number and type of airframers involved (Large passenger A/C, Regional A/C, business jet...), different set of specification will be established. It will allow the creation of different IEN solution fitting to each need.

To answer those specifications, IEN will be studied and designed in 5 WPs. 4 topics will be generic, not dedicated to the architecture: distribution, conversion, return network and the network management.

Distribution one will focuses on key technologies needed to enable and support the different topologies (bus, meshed network...). The conversion WP deals with power electronics and cooling. The network WP focuses on health monitoring, communication and management algorithms.

The last one will be on the system integration. The V&V will be specific to the use case defined. Different bricks developed in previous WP will be assembled to build and test the IEN.
**Description of added value of the demo / techno vs. state of the art**

The added value of the Innovative Electrical Network (IEN) will be visible at system and at equipment level, with trade-offs that would allow:

- Overall weight saving at system level. Preliminary studies showed 15% potential saving for meshed network compared to traditional topologies
- Optimized Energy consumption through better management and simplified EWIS
- Comprehensive health monitoring capability and enhanced dispatch reliability through modularity and re-configurability of the IEN
- Implement future networks functionalities, increasing overall availability of electrical power by enabling reconfigurations
- Ability to take multiple types of sources and multiple types of users/loads, hence increasing overall availability of the electrical power supply.
- Lower costs mainly through re-use and increased modularity of the equipment, advanced racking and mutualization.
- Introduction of power Line Communication (PLC) within the electrical network system
- Introduction of advanced network protection (i(t), arc-fault, lightning.
- Specific EWIS improvements (cable technology, connective items, installation and tools)

**High level plan with schedule, major milestones, deliverables, TRL to target**
The key planning interaction is to be on-time for delivery to the COPPER Bird® platform at the beginning of the commissioning and to be tested with all available aircraft functions as an integral part of the network. This ties-in with the IEW project as one of the main load-systems to be interacted with.

The major deliveries will be linked to the major function/technology to develop:
- Multi-Loads and multi-sources management and connection
- Electrical conversion
- EWIS health monitoring
- Advanced racks
- Network protection (i(t), arcs, etc.)
- Communication
- EWIS technology and installation

The distribution boxes will be interconnected and communicate together to control the network state. Use of traditional wired solutions will be kept, as a back up, to ensure that this brick will not be a showstopper for the network feasibility.
Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD

The final demo will then be forwarded to the WP 6.4.1 “COPPER Bird®” in order to be tested.

Expected high level added value per demo / techno wrt. H2020 objectives

Following benefits are expected from this project:

- **Competitiveness:**
  - Optimized Energy consumption: -5% compared to traditional topology
  - Electrical system weight reduction: -15% compared to traditional topologies
  - Simplify EWIS installation (by reducing number of wires): -20% (in length) compared to traditional star topologies on a MEA
  - Innovative generic “bricks” gathering Rack, Health monitoring, EWIS protection, Power electronic, EWIS technology... This brick will reach a good maturity level at the end of the project: TRL5 min. It will be an enabler for innovative topologies at the start of an airframe program.
  - Leadership on new electronics & electrical equipment and system market.
- **Environmental:** Reduced environmental impact through optimized energy use but also due to weight reduction
b. **Electrical Power Management Center**

**o Background – Clean Sky activities (or in other EU/National projects)**

In the frame of *Clean Sky* SGO ITD, several key technologies are delivered to address the needs of power management of aircraft energy.

In particular, a power management modular bay was developed and will be tested with the following objectives:

- Validation of the power distribution center architecture;
- Optimization and improvement of the performance and weight of the major components with focus on power electronics modules. The power density of these PEM is about 4kW/kg;
- Test validation in PROVEN test rig with representative loads (ECS, etc.).

**o High-level objectives at demonstrator / technology levels**

The next step in *Clean Sky* 2 will be the optimisation of the Power distribution center architecture and to integrate new functionalities for large aircraft and bizjet aircraft. The concept will cope with systems architectures, permitting to achieve safety goals and aircraft certification. The activities will address these following tasks:

- Perform a trade-off to define the perimeter and the topology of the power distribution center by introducing a ‘trans-ATA’ approach. The associativity with dedicated power electronics modules for specific loads will be also considered.
- Increase the performance and maturity aspects by integrating a new higher power density generation of PEM with monitoring functionalities,
- Analyse power management functions to ensure the multi ATA applications
- Improve dispatch capabilities in case of failure mode
- Optimize the cooling system performance and reliability

In addition, the technological bricks to adapt the Power management center for Bizjet aircraft applications will be developed.

To achieve these objectives, many challenges will have to deal with various technologies and methodologies at different levels, i.e. System, equipment and technology.
Description of added value of the demo / techno vs. state of the art

Compared to the state of the art, these activities will enable to increase to improve significantly the power management capabilities with a modular approach in order to improve the overall electromechanical chain from generation to distribution. Moreover, extension of perimeter with deletion of conventional ATA frontiers and potential increase of mutualisation power electronics for instance will lead to increase the benefits at aircraft level.

This project will address many different technology studies and methodologies process:
- Simulation and modelling the complete electrical chain,
- Test the reconfiguration with several loads (Generation, ECS, etc.),
- Integrating and test health monitoring functions for maintenance facilities,
- Develop incremental certification and safety analyse framework on the complete power management functions.

The activities related to power electronics modules will address many different technology studies and methodologies process:
- Materials for passive components for high temperature operation
- Power transistor with SiC and GAN technologies for high temperature and high frequency operation
- High performance and reliable cooling System
- Integrating health monitoring functions for maintenance facilities
- Introduction of dispatch capabilities
- Standardization power electrical module.
- High power density modules using highly integrated power devices, gate drivers and sensors
- Innovative motor control schemes and control electronics
- Compact filtering solutions
Clean Sky 2 Joint Technology Initiative in Aeronautics

- High-level plan with schedule, major milestones, deliverables, TRL to target

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For each TRL level the following tasks are foreseen:

- Development and conception will be progressed through usual milestones of work reviews: specification review, preliminary design review (PDR), conception design review (CDR), test plan review and TRL assessment review.
- Equipment realization, the amount of equipment will be depending on TRL level:
  - for TRL 4, one mock-up to evaluate and to choose the technological bricks in laboratory environment,
  - for TRL 5, one prototype to be evaluated in a representative environment,
  - for TRL 6, one TRL 5 prototype with necessary modifications interfaces to be integrated in a complete system with representative environment (tests on IronBird or flight tests).
Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD

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<td>5.2.2 5.2.3</td>
<td>WP6: Cooling system and EECS WP6.4: test facilities GETI and PROVEN.</td>
<td>LPA and RA: - Platform 2 for flight test preparation - electrical and mechanical interfaces (ICD) - Test plan contribution for evaluation - participation TRL Assessment reviews</td>
<td>Demonstrator deliveries: - LPA IADP (link with Platform 2 –WP0): PEM, and energy management laws, architecture and system studies - RA IADP (link with WP2.3 energy optimized RA and link with WP2.3.4 advanced EPGDS): integrated modular power electronics bay - FR IADP (link with WP8 Electrical system:power management bay</td>
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<td>↔ WP5: Starter generator</td>
<td>↔ ECO: Material and Processes</td>
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<td>↔ WP6.4: Test facilities GETI and PROVEN</td>
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<td>→ TE: Relevant inputs for models</td>
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Expected high level added value per demo / techno wrt. H2020 objectives

With respect to the H2020 and ACARE targets, this work package is expected to provide benefits in the following respects:

- **Environmental**: Fuel consumption reduction due to removal of bleed air from engines and through more efficient use of A/C energy

- **Competitiveness**:
  - Reduction in maintenance costs through reliability gains at a system level;
  - Improvement of aircraft availability by increasing systems reconfiguration capabilities;
  - System optimization and trans-ATA mutualization helps to A/C optimized architectures.
IV. Power Conversion

a. Active Power Conversion for DC & AC/DC Networks

o Background – Clean Sky activities (or in other EU/National projects)

Activities have taken place in Clean Sky SGO 5 the A/C level assessment and exploitation and delivery of key technologies have been performed to address the future electrical network for more electrical aircraft (MEA). A bi-way demonstrator with TRL3/4 maturity level will be delivered in COPPER test bench in the middle of the year 2014. This demonstrator added with internal DC-DC and AC-DC converter developments contribute to define the starting point for Clean Sky 2 project.

These evolutions will be always compared to the classical passive conversion as ATRU and TRU equipment, for which robustness and availability are proven even if the weight seems to be a negative aspect for the next generation of airplane.

Also this solution allowed high reliability propositions with new electrical architecture System associated with new electrical functionalities:

- regulated low voltage network bus and develop standard converter to address charger battery function (BCRU Battery Charger Regulated Unit)
- reversible DC-DC conversion to mutualise the electrical chain for electrical machine using in both generator and motor modes and also to converter DC voltage between low DC voltage network and High voltage DC network (Bi-way converter)
- controlled rectifier for AC to HVDC network (RU Rectifier Unit). This function is expected with generator activities but also with power factor corrector (PFC) function (RTRU regulated Transformer rectifier unit equipment integrating PFC function)

This project will contribute to reach main objectives of More Electric Aircraft:
- Simplify power network aircraft
- Reduce the total weight at aircraft level
- assure the quality of AC and HVDC power network
- High-level objectives at demonstrator / technology levels

In the frame of Clean Sky 2, proposal is to analyse the gain of integrating new functions in electrical network for large, regional and helicopter aircraft architecture. The adopted solutions will be develop to reach the high maturity level TRL5 to be integrated in demonstrator bench and as possible in flight test.

The main objectives of the programme are as follows:

- DC-DC Conversion with reversible and regulated network functions to optimize power network aircraft;
- AC-DC conversion with control rectifier and with power factor correction to maximize the quality of AC network
- Conversion with high availability and robustness level;
- Increase the maturity level of adopted solution of conversion with the integration of technological bricks:
  - Integrate new generation active component
  - PCB technology compatible with high currents,
  - Passive component with low parasite effect and high power density (planar transformer and inductance)
  - Improve accuracy of sensors in disturbed environment and evaluate less sensible sensor health monitoring for power electronic component
- collaboration with a core partner which will be selected in WP 5.1.4, to specify and to integrate battery prototype

In addition of these tasks and throughout all the project duration, new opportunities will be analysed to challenge the current solutions.

- Description of added value of the demo / techno vs. state of the art

The integration of new functions would be an opportunity to reduce the weight of electronic and cable mounted on board and to challenge the reliability of the electrical power network.

Today, rectifier unit and PFC module are developed with passive conversion through diode and multi pulse transformer. Objectives are to provide similar functions through active conversion with controlled rectifier and PFC converter.

For active converter, the reached density power is on average close to 1Kw/kg, through the integration of technology bricks, the expected density power will be to double.
High-level plan with schedule, major milestones, deliverables, TRL to target

Dedicated power conversion activities in Clean Sky 2 will focus on high TRL (5 and 6) to test new technologies and concepts in representative environment as presented in the below schedule:

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<td>AC-DC power conversion : Rectifier unit with CS1 PEM</td>
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<td>For conversion equipment, the following activities are expected: WP 6.1 for interaction with E-ECS WP 5.2 for interaction with modular centralized power bay. WP6.4 : test facilities GETI and PROVEN WP5.1 : specification with power network</td>
<td>LPA AIDP, RA IADP and Rotorcraft (FR IADP): Power conversion specifications electrical and mechanical interfaces (ICD) Test plan contribution for evaluation participation TRL Assessment reviews ECO : material and processes</td>
<td>Demonstrator deliveries: LPA IADP (link with Platform 2 –WP0): DC-DC converter and rectifier uniti (RU) tested on PROVEN test Bench. RA IADP ( link with WP2.3 energy optimized RA and link with WP2.3.4 advanced EPGDS ): DC-DC converter for reversible electrical chain with battery charger FR IADP (link with WP6 system &amp; equipment T6.1 EPGDS : DC-DC converter for reversible electrical chain and BCU ECO : evaluation</td>
</tr>
</tbody>
</table>

o Expected high level added value per demo / techno wrt. H2020 objectives

- **Environmental**: Fuel consumption reduction will be weight savings with higher power density converter with mutualising equipment.
- **Competitiveness**: Reduction of operative costs through simplify electrical power network by reducing number of equipment and number of power cables. Product life by improving reparability and maintainability capabilities with integration of health monitoring functions for power electronic components
- **Societal**: Proposed developments and collaborations will open opportunities for research and future business for the European supply chain (automotive industry and power component maker) and Academia.
11.6.6 Major Loads – WP6

I. Air Systems and Thermal Management

a. Electrical ECS for Large Aircraft

- Background – Clean Sky activities (or in other EU/National projects)

In the frame of Clean Sky Systems for Green Operations ITD, several technological bricks (air cycle machine, vapour cycle compressor etc.) are developed to address needs for a future Electrical ECS for Large Aircraft configuration. The activities are based on the electrical driven air conditioning system developed within MOET project (FP6) with the following objectives:

- Optimization and improvement of the maturity and robustness of the major components (turbomachines, pack controller and power electronics). Tests have been conducted at components level and system level (see fig. 1) in a relevant dedicated altitude chamber at LIEBHERR.
- Trade-off on new electrical ECS architectures extended to the thermal management perimeter. Some additional studies still need to be performed in order to achieve the additional savings expected (weight, power consumption, etc.) for future electrical aircraft.
- Development of a VCS demonstrator based on a new centrifugal compressor and refrigerant fluid (see fig. 2) which will be tested on LIEBHERR facilities and should be integrated in AVANT test bench (Airbus) for validation of thermal management architecture and functions.
- Development of a flight test demonstrator to minimum qualification for safety of flight. The flight test campaign will be conducted in Sept 2015 and will enable to validate:
  - The installation and integration (mechanically and electrically) in A320 platform;
  - The interaction between air intake and ECS turbocompressors;
  - The control laws robustness in transient modes;
  - Air quality preliminary assessment.

Completion of these different studies and demonstrations will allow LIEBHERR to reach a TRL 5 for an electrical ECS pack and power electronics.

- High level objectives at demonstrator / technology levels

The next step in Clean Sky 2 will be the integration and optimisation of these components into a high performance system solution corresponding to future needs for a single aisle. In particular, performances objectives will be achieved by combining cycle air part with improved vapour cycle system. Moreover, E-ECS
architecture for large aircraft configuration will be optimized with respect to system impact on weight and power consumption, reliability, drag increase and enhanced engine power efficiency.

The proposed detailed objectives are:

- Refinement of EECS architectures (including thermal management perimeter) for a single-aisle application based on experience gained on Clean Sky studies and demonstrations and with extension of studied perimeter with:
  - Inerting systems;
  - Aircraft air distribution and management (cargo and avionics bay ventilation, etc.);
  - Trans-ATA consideration.
- Maturity achievement and validation for major technological bricks like:
  - Full-scale turbomachines;
  - Full-scale power electronics including multi-use capabilities (refer to 3. Power Management);
  - Centrifugal VCS compressor;
  - Separation devices for EECS air inlet protection and improvement of cabin air quality;
  - Innovative solutions to improve cabin comfort (humidity, temperature, etc.).
- Development of system demonstrators which will be validated:
  - On ground in LIEBHERR facilities to address extended perimeter and power management capabilities (refer to WP3. Power management and WP5. Demonstration on GETI demonstration);
  - On ground in Airbus PROVEN test bench to address electrical topics validation;
  - On ground in the equipped fuselage demonstrator and potentially in flight (if necessity confirmed) in LPA IADP Platform 2 with a demonstrator covering:
    - Full scale performance for single-aisle configuration;
    - E-ECS pack and supplemental recirculation cooling with VCS;
    - Power Electronics (potentially integrated in modular centralized power bay) with capability to drive a starter-generator for Main Engine Start.

- Description of added value of the demo / techno vs. state of the art

Up to now aircraft systems have been designed mainly from a safety, time efficiency and affordability viewpoint. The increasing social demand to reduce fuel consumption, emissions and noise leads to the adoption of a new approach when designing systems. Electrical aircraft is one of the major contributors to achieve these high level objectives.

Development of new architectures for Environmental Control System based on electrical technologies compared to today conventional pneumatic solutions will allow significant:

- Fuel consumption reduction through more efficient use of A/C energies
- Improvement of A/C availability by increasing systems reconfiguration capabilities

Yet, electrical technologies and preliminarily envisaged architectures are today known to be heavier and more expensive compared to existing solutions which reduce significantly the expected benefits at A/C level.

Therefore, extension of perimeter with deletion of conventional ATA frontiers and potential increase of mutualisation of A/C resources and components (power electronics for instance) will lead to compensate these identified weaknesses and to raise blockages towards electrical aircraft.
In addition, removal of bleed air from engines associated with the development of means for air treatment adapted to Electrical ECS will improve air quality and comfort for aircraft occupants.

- **High-level plan with schedule, major milestones, deliverables, TRL to target**

- **Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD**

<table>
<thead>
<tr>
<th>Operational WPs</th>
<th>Inputs/Outputs in ITD Systems</th>
<th>Inputs from other ITD/IADP</th>
<th>Output to other ITD/IADP</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1 ↔ WP6:</td>
<td>Cooling system</td>
<td>← LPA: Platform 2: Requirements for tests in integrated fuselage-cabin-cargo-systems demonstrator Platform 2 for flight test preparation (if necessity confirmed)</td>
<td>→ LPA: Platform 2: EECS to be tested in integrated fuselage-cabin-cargo-systems demonstrator flight validation (if necessity confirmed)</td>
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<td>← ECO: Material and Processes</td>
<td>→ ECO: Material and Processes</td>
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<td>← WP5: Starter generator and Electrical Power Management Center</td>
<td>→ TE: Relevant inputs for models</td>
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<td></td>
<td></td>
<td>← WP6.4: Test facilities GETI and PROVEN</td>
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</tbody>
</table>
- **Expected high level added value per demo / techno wrt. H2020 objectives**

  With respect to the H2020 and ACARE targets, this work package is expected to provide benefits in the following respects:

  - **Environmental:** Fuel consumption reduction due to removal of bleed air from engines and through more efficient use of A/C energy
  - **Competitiveness:**
    - Reduction in maintenance costs through reliability gains at a system level.
    - Improvement of aircraft availability by increasing systems reconfiguration capabilities
    - System optimization and trans-ATA mutualization helps to A/C optimized architectures
  - **Societal:** Customer Satisfaction: Improvement of air quality, passenger comfort and safety

**b. Next Generation EECS Demonstrator for Regional A/C**

- **Background – Clean Sky activities**

  In the framework of Clean Sky SGO WP 2.3.4.1.2 Environmental Control System for Regional Aircraft, LIEBHERR and Alenia objectives were:

  - To design, manufacture/procure and perform development tests (including SoF) of the E-ECS demonstrator for the in-flight demonstration (performed within the GRA ITD);
  - To adapt the demonstrator developed in the EDS ITD for the on-ground Electrical Bench (control laws and consumption profiles for specific demonstration for Regional platform).

  Thus, the demonstrations that are performed in Clean Sky will lead to A/C integration and electrical energy management validation but not at a representative scale for future Regional A/C and without performance demonstration. These two last points need to be demonstrated in Clean Sky 2.

- **High level objectives at demonstrator / technology levels**

  The major objectives of the “Next Generation EECS Demonstrator for Regional A/C” are:

  - To achieve performance target in terms of environmental control at a fully representative scale for Regional A/C, according to the system architecture defined within the Regional A/C IADP,
  - To work and support validation on specific aspects of cabin comfort optimisation (temperature control & humidification / dehumidification) and support validation on other comfort cabin aspects (ventilation, pressurization & air stratification) in the framework of Regional A/C IADP on a fuselage section fully representative of the Regional Aircraft configuration, so called Thermal test bench.
- **Description of added value of the demo / techno vs. state of the art**

Being a high power consuming system, E-ECS is a key driver to allow implementation of more/all-electric aircraft and achieve a better engine power exploitation by introducing more efficient bleedless engines in the Regional Aircraft configuration.

E-ECS optimisation shall mainly target the mitigation of the different drawbacks with respect to traditional, bleed-based ECS, such as weight and penalties, need for high amount of electrical power, reduced reliability.

- **High level plan with schedule, major milestones, deliverables, TRL to target**

  o E-ECS architecture selection: end 2015 (Regional A/C IADP)
  o E-ECS Demonstrator availability, deliverable for Laboratory tests: end 2018
  o E-ECS Laboratory Test accomplishment (performance demonstration): end 2019 > TRL 4 reached
  o E-ECS available, deliverable for Thermal Bench: end 2019
  o E-ECS Test on Thermal Bench accomplishment (cabin comfort demonstration): end 2020 > TRL 5 (Regional A/C IADP)

- **Interaction and interfaces with other ITDs / IADPs / TE / ECO and within ITD Systems**

<table>
<thead>
<tr>
<th>Operational WPs</th>
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<tbody>
<tr>
<td>↔ WP6:</td>
<td>↔ WP6: Cooling system and Large EECS</td>
<td>↔ Regional AC: WP 2.3.3, 2.3.5 &amp; 3.2</td>
<td>→ Regional AC: WP 2.3.3, 2.3.5 &amp; 3.2</td>
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<td>↔ WP100.1:</td>
<td>↔ WP100.1: Power electronic</td>
<td>↔ ECO: Material and Processes</td>
<td>→ ECO: Material and Processes</td>
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<tr>
<td>↔ WP6.4:</td>
<td>↔ WP6.4: Test facilities</td>
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<td>→ TE: Relevant inputs for models</td>
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</table>

- **Expected high level added value per demo / techno wrt. H2020 objectives**

  With respect to the H2020 and ACARE targets, this demonstrator is expected to provide benefits in the following respects:

  o **Environmental:**
    - Energy Efficiency and CO₂: 2 to 3% fuel burn and associated emissions reductions at aircraft level;
    - Green Design: Maximized utilization of green materials and processed.

  o **Competitiveness:**
    - Acquisition cost: E-ECS acquisition will lead to lower cost compared to an equivalent pneumatic system due to the gains induced through electrical integration at A/C level;
    - Reduction in maintenance cost through reliability gains at system level.

  o **Societal:** Reduction of emissions will lead to lower impact on health.

- **New Generation of Cooling Systems**

  - **Background – Clean Sky activities (or in other EU/National projects)**
In the frame of WP2.3.6 of Systems for Green Operations ITD, LIEBHERR objectives are to develop the technological bricks to address the needs of thermal management for future single aisle aircraft configuration.

In particular, a VCS demonstrator based on new centrifugal compressor and using refrigerant fluid compliant with future environmental regulations (GWP limitations) was developed and tested in LIEBHERR facilities. This demonstrator will be integrated in AVANT test rig (Airbus) for validation of thermal management architecture and functions.

These demonstrations will allow LIEBHERR to reach a TRL 4/5 for vapour cycle system including centrifugal compressor and associated system control.

- **High level objectives at demonstrator / technology levels**

In the frame of *Clean Sky 2*, LIEBHERR will design, manufacture and test new generation of Supplemental Cooling System.

The proposed detailed objectives are:

- Selection of new generation fluid compliant with environmental future rules and aerospace certification constrains
- Trade-off between volumetric and centrifugal technologies and identification of the appropriate technology according to the cooling needs
- Development of a high performance compressor integrating:
  - Optimized architecture for high efficient autonomous cooling and adapted to the cooling needs
  - New aerodynamic compressor stage optimized for new selected refrigerant
  - New generation of electrical motor
  - High density power inverter
- Design and development of valve optimized for dynamic regulation of vapour cycle system
- Control capabilities (refrigerant flow measurement, etc.) improvement and definition of an optimized control strategy
- Design an optimization of heat Exchanger optimized for VCS application
- Minimum qualification for flight test demonstration

- **Description of added value of the demo / techno vs. state of the art**

Compared to the state of the art, these studies will contribute to introduce new generation of Supplemental Cooling system with lower weight compared to existing solutions. Moreover, these developments will be compliant with future aerospace regulations and optimized for new single aisle objectives.

- **High-level plan with schedule, major milestones, deliverables, TRL to target**
Interaction and interfaces with other ITDs / IADPs / TE / ECO and within ITD Systems

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>6.1</td>
<td>↔ WP6: Large and Regional EECS</td>
<td>↔ LPA: Platform 2</td>
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<td>↔ WP100.1: Power electronic</td>
<td>↔ ECO: Material and Processes</td>
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<td>↔ WP6.4: Test facility GETI</td>
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<td>→ TE: Relevant inputs for models</td>
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Expected high level added value per demo / techno wrt. H2020 objectives

With respect to the H2020 and ACARE targets, this activity is expected to provide benefits in the following respects:

- **Environmental:**
  - Fuel consumption reduction due to weight reduction
  - Introduction of new generation fluid compliant with environmental future rules
- **Competitiveness:**
  - Reduction in maintenance costs through reliability gains at a system level.
  - Improvement of aircraft availability by increasing cooling system reconfiguration capabilities
II. **Other Loads**

1) **Electrical Motors**

a. **High Power Motors for major load**

   - **Background – Clean Sky activities**

   Activity non developed in Clean Sky, but new opportunities to communalize knowledge and experiences about designed, developed and manufactured high power electrical machines. For this application, the expected electrical motor performances are close to 100kW in steady state. The starting point for Clean Sky 2 project is TRL3 maturity level reached in the last past few years (2012/2013) through internal R&T projects for which demonstrators were developed for green taxiing (TRL3) and E-ECS applications (TRL3). For these activities, power electronics module (PEM) developed in clean Sky 1 project with TLR3/4 maturity level will be the starting point for the control unit associated to the motor.

   ![Motor for dedicated power generation (mock-up view)](image)

   - **High level objectives at demonstrator / technology levels**

The major objective of “other major loads” project is to mature the concept by developing a new generation of electrical motors which are compliant with A/C conditions and specifically large aircraft environment. The previous demonstrator was developed with partners working in non-aeronautic domain. The concept will scope with system architectures, permitting to achieve safety goals and aircraft certification. The activities will address these following tasks:

- Increase the maturity level of high speed and high integrated motor,
- Compartmental modelling and multi-physical simulation,
- Introduce high speed rotation and high temperature material to produce integrated motor,
- Analyse consequences of higher speed rotation on mechanical structure and cooling System,
- Integrate electrical power System, re-using PEM technology already developed, adapting the frequency switching to the needs of the need of the application.
- Implement control software adapted to sensor or sensorless applications.
- **Description of added value of the demo / techno vs. state of the art**

The added value of the demonstrator is to validate the concept of high integrated electrical motor. The demonstrator will be an opportunity to develop industrial process on new designing and manufacturing techniques for this type of electrical motor. Validation of manufacturing processes is foreseen to mitigate potential risks in the future industrial development.

The electrical motor speed range for A/C applications is between ten thousand RPM and fifty to seventy thousand RPM. If electrical motor maturity is reached for the low part of this speed range, the interest today is to manufacture electrical motors running at high speed to gain power density. The high level of mechanical constraints on the rotating part requires mastering manufacturing techniques like carbon fibre sleeve. In addition to this activity, electromagnetic, thermal and mechanical designs will be conducted in order to master the safe operation of these demonstrators dedicated to A/C applications.

- **High-level plan with schedule, major milestones, deliverables, TRL to target**

Motors for dedicated power generation activities in *Clean Sky 2* will focus on high TRL 4/5 to test new technologies and concepts in representative environment.

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<td>Electrical motor</td>
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<td>Motors for major load (High power)</td>
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</table>

For each TRL level the following tasks are foreseen:

- Development and conception will be progressed through usual milestones of work reviews: specification review, preliminary design review (PDR), conception design review (CDR), test plan review and TRL assessment review
- Equipment realization, the number of equipment will be depending on TRL level:
  - for TRL 4, one mock-up to evaluate and to choose the technological bricks in laboratory environment,
  - for TRL 5, one prototype to be evaluated in a representative environment,
  - for TRL 6, one TRL 5 prototype with necessary modifications interfaces to be integrated in a complete system with representative environment (tests on Iron Bird or flight tests).
Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD

<table>
<thead>
<tr>
<th>Operational WPs</th>
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</tr>
</thead>
</table>
| WP6.3           | For power electrical motor equipment, the following activities are expected:  
• WP5.1 power network specification  
• WP 5.2 for interaction with modular centralized power bay.  
• WP6.4: test facilities GETI and PROVEN  
• WP5.1.3: power conversion specification | LPA AIDP, RA IADP and Rotorcraft (FR IADP): Network specifications Critical load specifications ECO: material and processes | Demonstration equipment for IADP test bench. Demonstrator deliveries: LPA IADP (link with Platform 2 – WP0): major load motor for green taxiing or E-ECS or hydraulic pump FR IADP (link with WP6 system & equipment T6.1 EPGDS: hydraulic pump ECO : evaluation |

Expected high level added value per demo / techno wrt. H2020 objectives

- **Environmental**: Fuel consumption reduction will be:
  - Optimized efficiency
  - Reduction weight, by increase power density
- **Competitiveness**: Reduction of operative costs through robustness electrical motor. Increasing the availability through integration of sensor less control laws
- **Societal**: Proposed developments and collaborations will open opportunities for research and future business for the European supply chain and Academia.
b. **Low power motors**

- **Background – Clean Sky activities**

Activity non developed in *Clean Sky*, but new opportunities to benefit knowledges and experiences about designed, developed and manufactured low power electrical motors. For this project, the targets are to progress on designing electrical motor in high-energy applications and in sensorless digital control, the targeted electrical power for this project is a few kW. TRL3 maturity level is reached through R&T internal projects and this milestone will be the starting point for the *Clean Sky* 2 project.

- **High level objectives at demonstrator / technology levels**

The major objective of “low power motors” project is to mature the concept by developing a demonstrator provided with its digital control. The design will comply with A/C conditions and harsh environment. The concept will scope with systems architectures, permitting to achieve safety goals and aircraft certification. The activities will address these following tasks:

- Increase the maturity level of low power motor complied with harsh environment,
- Compartmental modelling and multi-physical simulation for sensorless digital control,
- Study new topologies to improve power quality,
- Introduce high temperature material to produce integrated motor,
- Analyse consequences of higher speed rotation on mechanical structure and cooling System,
- Certificated approach for electronic control.

- **Description of added value of the demo / techno vs. state of the art**

The added value of the demonstrator is to develop sensorless digital control for different ranges of electrical power and high integrated permanent magnet motor. The interest is to continue to improve speed loop software using field oriented control. Today validation was reached for low load, but need to be performed for higher torque at low speed.

The demonstrator will be an opportunity to consolidate industrial process on new designing and manufacturing techniques for this type of electrical motor.
- High level plan with schedule, major milestones, deliverables, TRL to target

Low power Motors activities in *Clean Sky 2* will focus on high TRL (4 and 5) to test new technologies and concepts in representative environment.

|-------------------------|------------------|------------------------------------------------------------------|------|------|------|------|------|------|
| Motors for major load   | Sensorless Control unit | • State of art  
• Simulation  
• Experimental tests  
• Integration algorithm | TRL 3 | TRL 4 |

For each TRL level the following tasks are foreseen:

- Development and conception will be progressed through usual milestones of work reviews: specification review, preliminary design review (PDR), conception design review (CDR), test plan review and TRL assessment review.

- Equipment realization, the number of equipment will be depending on TRL level:
  - For TRL 4, one mock-up to evaluate and to choose the technological bricks in laboratory environment,
  - for TRL 5, one prototype to be evaluated in a representative environment,
  - for TRL 6, one TRL 5 prototype with necessary modifications interfaces to be integrated in a complete system with representative environment (tests on Iron Bird or flight tests).
Interaction and interfaces with other ITDs / IADPs / TE / ECO

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</table>
| WP6.4           | For power electrical motor equipment, the following activities are expected:  
|                 | • WP5.1: power network specification  
|                 | • WP 5.3 for interaction with modular centralized power bay.  
|                 | • WP6.3: test facilities GETI and PROVEN  
|                 | • WP5.2: power conversion specification  
|                 | LPA AIDP, RA IADP and Rotorcraft (FR IADP):  
|                 | Network specifications  
|                 | Critical load specifications  
|                 | ECO: material and processes  
|                 | Demonstration equipment for IADP test bench.  
|                 | - Rotorcraft (FR IADP), Regional Aircraft (RA IADP) and Large Passager Aircraft (LPA IADP) could be relevant candidates.  
|                 | - ECO : evaluation |

Expected high level added value per demo / techno wrt. H2020 objectives

- **Environmental**: Fuel consumption reduction will be:  
  - Optimized efficiency  
  - Reduction weight, by increase power density
- **Competitiveness**: Reduction of operative costs through integration of sensor less control laws
- **Societal**: Proposed developments and collaborations will open opportunities for research and future business for the European supply chain and Academia.
11.6.7 Demonstration Platforms

I. Extended Cockpit

- Background

A significant part of the Clean Sky “System for Green Operations” ITD is devoted to Management of Trajectory and Mission activities. At mid-programme, current assessment of these new green trajectories and flight management functions show significant environmental gains for fuel consumption and CO₂ emissions in all flight phases as well as perceived noise in airport areas (see §1.2).

- High-level objectives

The strong results shown in Clean Sky confirm the need to further develop and demonstrate the flight management functions.

Beyond the green trajectories pioneered in Clean Sky, innovative flight management procedures and functions will be needed.

The new aircraft configurations developed in Clean Sky 2 will drive the development and integration of a coherent cockpit environment including displays, “eyes-out” technology, innovative HMI, virtualised control systems and modular computing, graphic and network resources.

Other innovative technologies and developments related to architecture, design, flight operations, crew activity and mission control will also be performed in the systems ITD.

The next integration step, to be passed in Clean Sky 2, is the combination of these individual demonstrations in an extended, integrated cockpit that can be assessed as a whole in different approaches, flight operations, crew interface and evaluation, integration in future air transport schemes, new functionalities, safety of flight, certification. This demonstration will secure the following objectives:

- Fully coherent, integrated cockpit environment, representative up to TRL5/TRL6, ready for assessment of new flight operations procedures: SESAR and NextGen, crew behaviour, crew workload optimisation;
- New systems management approach with a view to simplify crew activity and provide capabilities oriented information;
- Full-scale integration of Systems ITD developments to prepare customisation, deployment, further maturation and assessment in IADP demonstrators.

Many other significant research projects related to this extended cockpit perimeter are under way or soon to be launched. The objective of the Clean Sky 2 cockpit demonstrator is to use results from this research, and integrate all at a higher level, which would be impossible in a classical L2 due to the time and volume of activity needed for these activities. More specifically, the extended cockpit demonstrator will benefit from results from national projects and EU funded collaborative projects such as Clean Sky, ALICIA, ODICIS, SANDRA, SCARLETT, ASHLEY, etc.
The extended cockpit developed and demonstrated in the systems ITD will be the result of direct collaboration with Clean Sky 2 airframers, in order to capture their needs and meet their requirements. The resulting system will then be customised for, and delivered to the IADPs for further integration and maturation in specific contexts (large aircraft, regional aircraft, possibly rotorcraft).

Similar work, probably based on different concepts and hardware, will be performed to address the needs of Small Air Transport and converge for this segment towards the same objectives of environmental gain, enhanced crew operations and SESAR readiness.

### Planning

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Demonstrations / Activities</th>
</tr>
</thead>
</table>
| Flight Management     | • Green trajectories  
                       | • SESAR, nextgen integration  
                       | • Interactive FM                                                                 |
| Cockpit display system | • New crew environment  
                       | • Virtualised systems management  
                       | • HIS framework for faster to develop, customisable HSI  
                       | • Incremental certification                                                                 |
| Functions             | • Safety, surveillance  
                       | • Communication  
                       | • Navigation                                                                 |
| Platform & Networks    | • Full IMA platform addressing graphic generation, critical applications and cabin domain |
| Demonstrator          | • Integration,  
                       | • Assessment  
                       | • Customisation                                                                 |

[Diagram showing planning timeline with TRL stages for 2016-2020]
II. Electrical and Thermal testing facilities: general policy

Within ITD Systems, we are currently organising the test campaigns on three different test facilities that are COPPER Bird, GETI and PROVEN, respectively owned by SAFRAN, LIEBHERR together with Thales, and Airbus.

These facilities are covering different aspects of the required test areas and are planned to be used on a complementary basis, as shown on the following chart:

By testing of thermal aspects for regional aircraft oriented technologies, the test may be supervised by the aircraft manufacturer, through its IADP.

The actual tests dedicated to Rotorcraft applications may run directly into the Rotorcraft Platform to ease the integration on the aircraft.

The test facilities from the SAT activities will be hosted in the dedicated work package, but the need for tests is not fully defined yet.
III. COPPER Bird®

- Background – Clean Sky activities

COPPER Bird® is a test bench which was created in the frame of the FP5 project “Power Optimized Aircraft” (POA); its capabilities from test means point of view are currently upgraded in Clean Sky, where the COPPER Bird® (called “ETB”) is used as the unique ground electrical test bench to perform the test campaign for business jet, regional aircraft and rotorcraft more electrical configurations.

The goal of the ETB is to demonstrate and validate the technology maturity for more electric aircraft on large scale configurations (multi sources, complete distribution systems, multi-loads). It is an unavoidable tool to validate the TRL maturity of more electric equipments before being tested on flight tests.

The COPPER Bird® is involved in 4 ITDs in Clean Sky (Eco-Design, Green Regional Aircraft, Green Rotorcraft and Systems for Green Operations) and is managed as trans-ITD collaboration, involving partners, associates and leaders. A specific board (called “COPPER Board”) has been specifically created to manage the global activity of ETB on Clean Sky (schedule, risk management, technical activities, etc.).

- High level objectives at demonstrator / technology levels

The objective of the COPPER Bird® in Clean Sky 2 is to propose to all equipments providers and aircraft manufacturer a powerful and versatile ground test bench to validate the maturity of technologies, equipments and architectures.

It would be used to integrate new electrical distribution concepts, using many different sources (electrical generator or S/G, batteries, etc.) and providing power to the different equipments under tests.

The COPPER Bird® is by definition a highly cooperative platform where all the equipments suppliers and airframers can be gathered to go forward on maturity evaluation of new technologies, architectures and concepts.

- Description of added value of the demo / techno vs. state of the art

COPPER Bird® will offer the highest level of representativeness possible at ATA24 level, adding representativeness constraints which do not exist today for Clean Sky on ETB.

This is of prime importance for the innovative, more electrical platforms, but also for the critical systems that will rely on such electrical networks in the future (particularly primary and secondary flight control systems.)

A first COPPER Bird® standard will aim at the Innovative Electrical Wing (IEW: ITD Systems WP3.4.3) objectives of being able to test highly integrated Flight Control System (FCS) with optimized electrical actuators at TRL4, together with hosting the equipment/electrical loads that will become available at that same period of time (H2/2016).
A second standard will target configuration for the smart electrical networks, introducing Innovative Power Networks (in cooperation with Labinal), a second standard of E-Wing systems (incorporating DOP communications) and including the electrical subsystem part of the LGERS/EGTS, etc.

The COPPER BIRD® based on existing facilities and previous lessons learnt will be adapted with the following objectives:

- Key benefits:
  - Highly instrumented rig to de-risk integration of equipment before Iron Bird and A/C integration.
  - Fine-tuning of simulation models with respect to typical operation.
  - Normal and abnormal test scenarios as well as characterization tests
  - Verification of the power network configuration robustness

- Confidentiality, Security and Safety
- Multi-level simulation of electrical equipment
- Fully reconfigurable architecture
- Open to partnership platform.

The COPPER BIRD® in the Clean Sky 2 project, will be used by Dassault-Aviation and by Alenia[JRC49] to work on electrical systems for business jet and regional aircraft, to define new needs and adaptation increasing its representativeness and modularity. It will be used to integrate, test and mature the technologies, concepts and architectures developed in the frame of this program, as well as other equipment (HW and SW) coming from other R&T programs, as the European’s Electrical Test Bench continuing to support the Innovation take-off.

The adaptation of the means will be support in the different ITDs and the test will be support in the ITD systems.

- High-level plan with schedule, major milestones, deliverables, TRL to target
- **Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD**

<table>
<thead>
<tr>
<th>Innovative Electrical Network</th>
<th>Systems ITD</th>
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<tr>
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<td>Airframer X</td>
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<td>Participation</td>
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<tr>
<td>WP 6.4 COPPER BIRD® STD1</td>
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<tr>
<td>ETB Standard 1 Specification</td>
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<td>Design/ update</td>
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<td>Manufacturing and ATP</td>
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<td>Tests</td>
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<td>COPPER BIRD® STD2</td>
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- **Expected high level added value per demo / techno wrt. H2020 objectives**

No direct contribution to H2020 objectives, COPPER Bird® is a test platform to perform maturation of equipments.
IV. GETI

- **Background – Clean Sky activities (or in other EU/National projects)**

In the frame of GETI French national project (LIEBHERR and THALES AES partnership), a demonstration platform enabling to integrate and validate more electrical aircraft architectures was developed. This platform is based on modular approach and covers the coupled electrical/thermal management perimeter. The following functions were integrated and tested:

- Electrical generation
- Electrical distribution
- Electrical loads
- ECS system
- Liquid loop Cooling
- VCS system
- Power management
- Flexible system control bay enabling an optimized system control and allowing the integration of virtual model simulation for a complete architecture perimeter.

This platform is characterized by an open configuration enabling to integrate additional functions (sources or loads) and/or virtual models in control bay to cover a larger system perimeter by considering several aircraft configurations.

Moreover, GETI test bench can provide up to 500KW of electrical power supply and 5 kg/s of representative RAM air (dynamic pressure and temperature), in order to perform representative tests in full scale configuration.

- **High-level objectives at demonstrator / technology levels**

In the frame of Clean Sky 2, GETi test bench will be used as powerful and open platform demonstration enabling to validate the interaction between equipments/sub-systems and the global architecture optimized for electrical and thermal management.

In particular, GETI test bench will be used to:

- Validate the EECS architecture for single-aisle application extended to thermal management perimeter and by considering Trans-ATA interaction;
- Evaluate Power Electronics capabilities to drive multiple aircraft loads;
- Validate the Electrical power center (developed within WP5.3) integrating power modules dedicated to several loads. Tests to be performed in GETI test bench will enable to validate the dynamic management of major loads (E-ECS, WIPS, …) with a modular approach;
- Define a global vision including the electrical power center associated with dedicated power electronics for specific loads.
- **Description of added value of the demo / techno vs. state of the art**

The new architectures for future aircraft based on electrical technologies are expected to allow significant fuel consumption reduction and improvement of A/C availability by increasing systems reconfiguration capabilities. The extension of system perimeter with deletion of conventional ATA frontiers and by considering potential increase of mutualisation of A/C resources and components (power electronics for instance) appear to be the best way to obtain significant benefits compared to conventional architectures. Therefore, GETI test bench will provide a high added value in demonstration by allowing the validation of such complete architectures coupling electrical/thermal management perimeter.

- **High-level plan with schedule, major milestones, deliverables, TRL to target**

GETI test bench, as platform demonstration, will significantly contribute to the TRL targets defined for major components (EECS, Electrical power center, power electronics ...). It will also enable to validate global architectures covering electrical and thermal management perimeter.

- **Interaction and interfaces with other ITDs / IADPs / TE / ECO and within the Systems ITD**

<table>
<thead>
<tr>
<th>Operational WPs</th>
<th>Inputs/Outputs in ITD Systems</th>
<th>Inputs from other ITD/IADP</th>
<th>Output to other ITD/IADP</th>
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<tbody>
<tr>
<td>6.4</td>
<td>↔ WP6.1: electrical ECS and thermal management and others activities related to cooling technologies (Next generation supplemental cooling system, ...)</td>
<td></td>
<td>→ TE: Relevant inputs for models</td>
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</table>

- ↔ WP5.1: interaction with starter-generator developed by TAES
- ↔ WP5.2: interaction with conversion developed by TAES
- ↔ WP5.3: interaction with modular centralized power bay developed in collaboration with TAES and core partner.

- **Expected high-level added value per demo / techno wrt. H2020 objectives**

No direct contribution to H2020 objectives are expected since GETI test bench will be used as platform to evaluate the interaction between equipments/sub-systems and to validate a global architecture optimized for electrical and thermal management.
V. PROVEN\textsuperscript{LTS50}

- **Background – Clean Sky activities (or in other EU/National projects)**

PROVEN is a ground test rig located in Airbus facilities in Toulouse. This test rig is highly reconfigurable and dedicated to research and technology for aircraft electrical network. This capability allows studying a high variety of aircraft electrical network configuration. This test rig has already been used by Airbus in the MOET project during the 6th European framework programme.

It is made of the following elements:
- Electrical generation system
- Electrical distribution system
- Electrical loads / power users
- Control and monitoring room

- **High level objectives at demonstrator / technology levels**

The high level objectives of the PROVEN Platform are to execute as much as possible the required tests on ground to save some technologies flight tests. The magnitude of those savings is still to be defined with Airbus and is expected to be part of the 3\textsuperscript{rd} version of the JTP.

- **Description of added value of the demo / techno vs. state of the art**

The electrical generation system includes two driving stand that can accommodate up to 4 electrical generator. Two generators can be used in starting mode. Also additional power sources such as ground power unit or fuel cells can be connected to the electrical network. Different types of storage devices are also usable on the rig (batteries, supercapacitors). Power feeders' length can be adapted to be represented to be representative of different configurations of aircraft.

PROVEN includes its own power distribution centre but can also host new power centres delivered in collaborative projects such as Clean Sky SGO. A various range of voltage can be handled by the test rig.

PROVEN includes its own electrical load programmable bench to reproduce most of the characteristics of an electrical network On top of that, actual electrical power consumers can be installed (electrical supply, cooling, monitoring) in order to verify the correct integration of the equipment on the network.

Eventually, a control room offers different interfaces and allows:
- Operating the rig
- Collecting data from the tested systems
- Monitoring and recording parameters for further exploitation
- **High level plan with schedule, major milestones, deliverables, TRL to target**

PROVEN is a test facility and will contribute to validate the maturity of technologies developed for more electrical aircraft. The magnitude of those required tests is under investigation jointly with Airbus and will be detailed in the version 3 of the JTP.

- **Interaction and interfaces in Systems ID and with other ITDs / IADPs / TE / ECO**

Discussions with Airbus on-going, the detailed interactions table will be published with the version 3 of the JTP.

- **Expected high level added value per demo / techno wrt. H2020 objectives**

No direct contribution to H2020 objectives are expected since PROVEN test bench will be used as platform to evaluate the interaction between equipments/sub-systems and the electrical power network (including power supply)
11.7 SAT

As fully described in the “SAT” section of this document, the Systems ITD will address the specific needs of the Small Air Transport Aviation segment with a combination of:

- **Synergies**: through the application of technologies and systems developed for other segments and close enough to SAT needs to meet their requirements (electrical systems, actuation,…). This should also apply to some procedures and functions (SESAR insertion, datalink, pilot monitoring, …). Synergies will be identified and maximised in all Systems WPs during the definition phase.

- **Ad hoc developments**, when the SAT needs prove to be too specific when compared to other segments addressed in Systems. Certification, cost, weight, may be significant issues in this context and will lead to the development of dedicated solutions.
11.8 Interactions with other areas

11.8.1 Technology Evaluator

“Systems ITD” will develop, demonstrate and assess technologies that contribute to the Clean Sky 2 HLOs for environment, competitiveness and societal gains. As often as possible, these gains will be assessed at IADP level to be consolidated with other Clean Sky 2 results.

When this approach is not possible, and whenever relevant, ITD-level results will be communicated directly to the TE for consolidation outside IADP models. Please refer to demonstrators descriptions for case-by-case info on proposed approach.

TE interface will be managed and monitored as a permanent entry in the ITD PMC agenda. The description of the relevance of ITD results for TE purposes and the best way to deliver these results will be a mandatory part of the TRL gate process for all technologies.

11.8.2 Eco-Design

“Systems ITD” will develop, demonstrate and assess technologies. In many cases, this process will have relevance to – and may benefit from – eco-design activities in Clean Sky 2.

Whenever relevant, ITD-level results will be communicated to ED for consolidation. Please refer to demonstrators descriptions for case-by-case info on proposed approach.

ED interface will be managed and monitored as a permanent entry in the ITD PMC agenda. The description of the relevance of ITD results for TE purposes and the best way to deliver these results will be a mandatory part of the TRL process set in the IADP.

11.8.3 IADP, General Approach

Possible synergies on specific systems and technologies have been identified in a bilateral approach with the Clean Sky 2 IADP leaders. From this starting point, Interaction with the IADPs has been worked from two different angles.

- Requirements from different IADPs can be taken into account in a multi-target development and a generic solution can be defined with the potential to answer needs from different platforms. For example, power conversion equipment could be designed for a regional or rotorcraft platform, thus avoiding duplicating development costs. This is especially adapted to early steps, low-maturity developments; it is likely that specific versions of the development will branch out from the common starting point to answer specific constraints of both environments (generic + instantiations approach).
- An integrated ITD-IADP approach must be implemented in order to secure the maturation of technologies and functions and their integration in representative demonstrators. This calls for:
  - Overall System complexity management (Process Methodes & Tools) to be harmonized transversally.
Clean Sky 2 Joint Technology Initiative in Aeronautics

- Early involvement of airframers in the specification plus pre-architectural design and requirements phases' to prepare for future integration.
- Strong commitment of Systems partners to reach identified objectives in time for integration with IADPs.
- Strong commitment of IADP leaders to integrate and assess Systems deliverables as part of their demonstrators.

A first list of systems and functions proposed for full integration with IADPs is as follows:
(To be filled once discussions with airframers will be mature enough about commitment).

11.8.4 SESAR interface

While Clean Sky 2 is focused on technology-oriented, demonstration-driven objectives, it cannot be performed in isolation. It is obvious that the full benefit of these technologies will only be obtained if they are fully expressed in the rules and procedures of the overall future Air Transport system defined by SESAR, NextGen and similar initiatives. There is a strong need for bilateral information.

As SESAR and Clean Sky on one hand and SESAR 2020 and Clean Sky 2 on the other hand will be running in the same time span, a dual-way approach to synchronization is the best:

- Clean Sky 2 expects that SESAR will make available policy and organisation decisions when they are drafted, in order to foster technological initiatives in CS2 to maximize the operational benefits of these procedures (or to reconsider the operational benefit of a technology if it is not compatible with the foreseen SESAR concept of operations).
- Conversely, significant results obtained in Clean Sky 2 should be submitted to SESAR to maximise their operatopnal and procedural benefit in the ConOps.

Finally, a joint approach to both programmes should be implemented in order to avoid any duplication of effort.

Based on Clean Sky experience, Clean Sky 2 will implement SESAR interface in the Systems ITD in the form of a dedicated WP to exchange technical content and feedback with a mirror WP in SESAR/SESAR 2020. It is also necessary to maintain and formalize the JU-to-JU interface pioneered in Clean Sky.
12 Small Aircraft Transport (SAT)

12.1 Introduction

The European Small aircraft industry has a market position on the global general aviation and utility aircraft market, both pistons and turboprops (excluding business jets and new category of Light Sport Aircraft), of around 33% in value (total market 2002-2011 around $20Bn) thanks to the technical excellence resulting from past private investments covering all the segments like single/twin engines pistons and turboprops.

The North America and Europe regions have represented the two primary markets for this aircraft category, and have undergone a period of slow growth due to the global financial crisis and recession. Demand from other areas of the globe with higher economic growth, including emerging economies such as China, India, and Brazil, will grow in the next decades to complement orders from customers in North America and Europe. However, the cost of purchasing, maintaining and operating a small aircraft is a serious obstacle to higher growth in this market aviation sector.

Turboprop manufacturers of small utility/business aircraft have taken advantage of fuel prices increase in recent years, and partially cover the demand of a greater efficiency and lower operating costs aircraft. Although the general aviation/utility market is expected to remain vibrant throughout the next decade period, the development of a larger use of this category of aircraft in the passenger transport services is strongly related to breakthrough technologies in both power plant and airframe that dramatically reduces the impact on cost.

The US small aircraft manufacturers are historically predominant in the market and their positioning inside large companies (Textron) or acquisition by large non US investors (China) will allow them to operate and ensure continuously financial resources to launch new products development.

EU small aircraft industry invested in own funds in order to acquire a limited knowledge only to improve their current products but they do not have enough R&T&D resources capability to launch new products.

The fall of several national aircraft projects in this category have shown that the later development of such an aircraft has to be seen in an overall European context. Clean Sky 2 is defining the path for the next 9 years in European aeronautical industries and can enable European SAT community to develop jointly a small transport and utility aircraft capitalising the full weight capabilities of the CS-23 airworthiness regulations.

Leaders of SAT activities in CS2 are Evektor, spol. s r.o. (Ltd.) and Piaggio Aero Industries, S.p.A.

Evektor is a private commercial organization with highly-educated and skilled engineers. It is a leading design company in the Czech aerospace industry covering complete product development, testing and certification including installations of avionic systems. Its earlier successful participation in many other aerospace projects has flown into a contraction of its own project EV 55 Outback - twin-engine turboprop. Subsidiary Evektor Aerotechnik is one of the world’s largest manufacturers of light sport aircraft, advanced UL and very light airplanes, with over 40 years of experience in aircraft manufacturing, EASA certified production and sales network in 40+ countries all around the world.

Piaggio Aero Industries is a leading aeronautics firm in the international market. Piaggio Aero Industries S.p.A. is the only company in the world that is active in the design, construction and maintenance of both aircraft (business aviation and ISR) and aero engines. Advanced technology, experience and a strong commitment to research, combined with innovative style, have resulted in the Company's international success and have made it
a global brand in the business aviation. Presently Piaggio manufactures the P180 Avanti II, the Company flagship product, a twin-engine, turboprop executive aircraft powered by two pusher turboprop. The P180 is the fastest turboprop in production, which has been delivered to more than 200 countries worldwide.

12.2 SAT contribution to Clean Sky 2 goals and objectives

The Small Aircraft Initiative in Clean Sky 2 represents research and technology interests of European aircraft manufacturers of small aircraft used for passenger transport (up to 19 passengers) and for cargo transport, belonging to EASA’s CS-23 regulatory base, propelled by turbo engines. The small aircraft community interested in Clean Sky 2 is a group of more than 40 industrial companies (incl. many SMEs) accompanied by tens of research centres and universities. The community covers the whole supply chain, i.e. aircraft integrators, engine and systems manufacturers and research organizations.

Broader international cooperation with SAT community is further expanded by decision of SAT Leaders to use about to 20% of budget instead of up to 40% dedicated for Leaders and put more resources to open Core partners and Partners selection. It is expected, that as a Core partners will apply also European small aircraft manufacturers, which will together with Leaders define new concept of European 19 seats small aircraft and use results achieved in CS2 program to revitalize European small aircraft industry. The aim of SAT CS2 activities is to close gap between the small commuter customers’ expectations (cost, effective and safe product) and available technologies with dedicated R&T&D.

Based on the documents elaborated within the European Framework projects EPATS (European Personal Air Transportation System) and SAT-Rdmp (Small Aircraft Transport – Roadmap) were selected technical areas which support the achievement of Clean Sky 2 goals.

SAT approach takes into account inputs from accomplished or running FP6/FP7 projects. Serious commitment and operability was proved through past projects (namely level 2 projects CESAR, ESPOSA, level 1 projects SAFAR, CSAs EPATS, SAT-Rdmp etc.).

SAT established its technical proposal in a way to support Clean Sky 2 goals in a maximum way. The technologies will be developed, validated and integrated in Clean Sky 2 ITDs up to demonstrators reaching TRL6.
### Clean Sky 2 Joint Technology Initiative in Aeronautics

**Clean Sky 2 goal No1:** Creating resource efficient transport that respects the environment.

**Clean Sky 2 goal No2:** Ensuring safe and seamless mobility.

**Clean Sky 2 goal No3:** Win global leadership for European aeronautics with a competitive supply chain, incl. academia, REs and SMEs.

| I. Multimodality and passenger choice |  |
| II. Revitalization of European small aircraft industry |  |
| III. More safe and more efficient small aircraft operation |  |
| IV. Lower environmental impact (noise, fuel, energy) |  |
12.3 Work Breakdown Structure

To date, most key technologies for the future small aircraft have reached an intermediate level of maturity (TRL3-4). They need further efforts to reach a maturity level of TRL5 or TRL6 through both analytical and experimental demonstration. The following areas are addressed in particular ITDs in dedicated WPs:

**ITD Airframe** (see figures 9.14 and 9.16)

WP 0.2B – Small Air Transport Overall A/C Design & Configuration Management
WP B 1.2 – Optimized Composite Structures
WP B 2.3 – High Lift Wing (SAT)
WP B 3.4 – More Affordable Small a/c Manufacturing
WP B 3.5 – Advanced integration of systems in small a/c

**ITD Engines**

WP E.1 - Reliable and more efficient operation of small turbine engines (19 seats)
WP E.3 - Lightweight and fuel efficient compression ignition power unit

**ITD Systems**

WP S.1 - Efficient operation of small aircraft with affordable health monitoring systems
WP S.2 - More electric/electronic technologies for small aircraft
WP S.3 - Fly-by-wire architecture for small aircraft
WP S.4 - Affordable SESAR operation, modern cockpit and avionic solutions for small a/c
WP S.5 - Comfortable and safe cabin for small aircraft

To support transversal activities within (SAT) airframe ITD in particular and over all 3 ITDs with its SAT topics in general, one of the SAT overall A/C design tasks will be to establish a “reference aircraft” to define and to establish reference data for a conventional state-of-the-art 19-seater turbo-propelled aircraft against which the improvements of SAT Clean Sky 2 results can be measured and validated.
12.4 Description of SAT Participation

12.4.1 ITD Airframe

The SAT objective is to research and develop the application of more affordable and green technologies in the area of composite and metal aero structures used for small transport aircraft belonging to CS/FAR23 regulation category. These new technologies together with selected new ones from the systems will be integrated and validated on dedicated flying and ground demonstrators.

Based on the boundary conditions, SAT airframe WPs will focus on the utilization of cost effective materials and improvement of production technologies for fuselage and wing.

I. Small Air Transport Overall A/C Design & Configuration Management - WP0.2B

Interface & Cross-interaction Management

Supporting the goals of Clean Sky 2, this WP will, as a transversal coordination activity within the SAT group, coordinate research and application of technologies in all areas of aircraft design over all three ITDs and its WPs with SAT involvement. It will also support management and coordination activities for WP 0.0 within the airframe ITD in general.

Reference Aircraft

Actual available small transport aircraft types were initially developed and certified in the 50ies to 80ies of the last century, representing now 30 to 50 years old technologies. Upgrade programs for these aircraft enhance their capabilities only in certain areas (i.e. Avionics) while keeping its general limitations, mostly in the area of aircraft design weights and obsolete aircraft parts and systems.

SAT objectives, as outlined in the introduction of this chapter, supports research and application of new and cost effective technologies for a future new generation small transport aircraft using the full CS23 commuter weight range and with a strong focus on the overall aircraft costs in all areas, NRCs and RCs and total cost of ownership.

Important measure for these high level goals is to establish a “Reference aircraft” showing the actual status of performance, transport capabilities and most important actual costs of a recent aircraft type in the 19 seat commuter class. The results in all applicable SAT WPs which will be achieved during and at the end of Horizon2020 will be measured against this “Reference Aircraft” data by establishing a 19 seat future small aircraft concept. This task requires a multi-disciplinary aircraft design concept.

This WP will concentrate on

- Coordinate research and application of technologies in all areas of aircraft design;
- Define a state-of-the art “Reference Aircraft”;
- Research for and definition of a cost effective and competitive future small aircraft;
- Coordination of transversal activities over the ITD tasks with SAT involvement (call coordination, technology evaluator).
Major technology streams

- Multi-disciplinary aircraft design concept.

Demonstration activities

- DMU for a future small green aircraft in 19 seats commuter category;
- Concept and costs analysis future small green aircraft.
- The measurable goals of the future small aircraft concept are:
  1. Reduction of operating empty weight for baseline aircraft by 5% against “Reference aircraft”;
  2. Reduction of production cost by 15% against “Reference aircraft”;
  3. Reduction of fuel consumption by 15% against “Reference aircraft”.

Tentative planning, ref. aircraft

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II. Optimized Composite Structures – WP B 1.2

Actual wet laminate production methodologies applied for small aircraft has deficiencies in process stability and in subsequent reproducibility of specified shapes. Further on, it is based on manual production and allows limited automation.

Target of the WP is to increase the technology readiness level (typically from 4 to 5) of a shortlist of promising out of autoclave technologies mixing prepregs with thermoset dry fabrics to be infused with low pressure and low temperature resin system and mixing thermost and thermoplastic resins and/or prepregs

The demonstration activities will be performed with a strong focus on CS23 aircraft with aim of:

- increasing strength to cost and strength to weight ratios
- improving impact resistance
- higher integration level
- improve production stability

Composite aircraft structures in this WP will concentrate on

- The main aircraft structures of wing box, empennage and optional floats;
- Secondary aircraft structures nacelle designed and manufactured with the aim of low cost and weight;
- Investigation of possibilities of alternative materials for specific aircraft structures to support SAT aircraft capabilities for unpaved runways and for water operations;
- Investigate application of thermoplastics for damage exposed structures;
- Investigate the possibilities of metal-composite hybrid materials used for floats application;
- Focus on easy in field repair of composite structures.
The ability to repair composite structures is strongly linked to the design and the materials and processes used to manufacture the original part. A proper design for example takes into account sufficient edge distance to allow installation of oversized, larger repair fasteners, or uses a larger laminate thickness in bonded structures to allow a local bolted repair. However, a major obstacle in the repair of conventional autoclave cured composite parts is the need for high pressure during consolidation of a prepreg repair patch in order to obtain sufficient laminate quality, while in field mostly hot bonders are available which provide heat and vacuum at most. By designing and manufacturing the original composite parts using (Out of Autoclave) OOA prepregs, this mismatch in curing conditions during manufacture or repair is avoided.

- Investigation of exploitation and application of developed technology in out of aeronautics area like wind milling power stations.
- Thermoplastic materials.
- Automation of process.

In the EU project CESAR it was demonstrated that a combination of composites and automation by means of Automated Fibre Placement resulted in both a cost and weight reduction of the redesigned P180 canard wing. Also in the same project it was shown that the use of OOA prepregs resulted in a dramatic part count reduction of the Evektor Cobra canopy structure. The next logical step is to look at the combination and investigate the use of Automated Fibre Placement with OOA prepregs to manufacture cost effective composite structures.

Thermoplastic offers a number of advantages over thermoset composites of which the superior impact and damage resistant properties are perhaps the most relevant to the structural sizing. A disadvantage hampering further widespread use of thermoplastics is their relatively high material price compared to thermosets. Therefore thermoplastics should not be compared one-on-one with thermoset but be used where they offer the most potential of creating a light, cost-effective structure. Combined with possibility to weld thermoplastics, very
thin, damage resistant composite structures can be created. So, for example instead of using the light and stiff, but damage sensitive thermoset sandwich concept for flight control surfaces, these could be designed as a welded thermoplastic monolithic laminate structure.

Figure 14.2 - Illustrative picture of big composite structure produced by out of autoclave method

**Major technology streams**

- Investigating the possibilities of application of modern out of autoclave technologies like low pressure and low temperature pre-preg and liquid infusion methods in the area of production also enabling easy in-field repair possibilities;
- Investigating the possibilities of application of higher temperature resistant resin;
- Improvement of automation during production process of composite structures;
- Investigating the possibilities of application of hybrid materials;
- Investigation of application of modern thermoplastics for secondary aircraft structures using the better impact and damage tolerant capabilities compared to composite material.

**Demonstration activities**

- Design and manufacturing of a substantial part of a composite wing as an example for a main aircraft structures, static test
- Secondary aircraft structures nacelle designed and manufactured with automated production, static test, fire resistance test;
Tentative planning

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III. High Lift Wing (SAT) – WP B 2.3

Field performance of small transport aircraft, especially in the area of normal and commuter category is dominated by the propulsion (takeoff) and even more important by the reference speeds $V_2$ (takeoff safety speed) and $V_{REF}$ (landing reference speed). Both speeds are mostly based on multiples of the stall speed which is again driven by the maximum lift capabilities of the wing.

To support the goals of WP 0.2 for a future new generation small transport aircraft using the full CS23 commuter weight range requires improvement of the high lift capabilities to keep the stall speeds and the subsequent reference airspeed and field performance on the same level of available aircraft types with lower weights. The goal is to improve the high lift capabilities based on simple and cost effective system(s) which do not adversely affect the high speed performance and more important the overall aircraft cost structure.

This WP will concentrate on

- Research and development of cost effective high lift wing improvement;
- Design, manufacturing and test of aircraft wind tunnel models.

Major technology streams

- High/Low Speed Innovative Aerodynamic Concept.

Demonstration activities

Wind tunnel tests of 1/12 and ¼ scale wind tunnel models of future small green aircraft in the commuter category.

Tentative planning

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IV. More affordable small a/c manufacturing – WP B 3.4

The strong need to reduce cost of currently riveted airframe structures of small aircraft in low volume production was identified, pushes the research need towards the development of advanced metallic airframe and structures prognostic systems with:

- Reduction of manufacturing and assembly cost increasing the application of integral structure concept and use of automated assembly processes (i.e. the friction stir welding, integrated machined parts, additive manufacturing parts, alternative joining technologies; free fasteners joining technologies)
- New concepts of assembly jigs and tools (robotic assisted assembly in low volume production).

![Decrease of DOC & IOC by 8%](image)

Figure 14.3 – Illustrative diagram of decreasing DOC – Direct Operating Costs and IOC – Indirect Operating Costs

In the EU project WELAIR, the application of FSW to fuselage barrel of P180 aircraft resulted in both cost and weight reduction, demonstrating that FSW welding process can maintain the high strength and fatigue properties of aluminium alloys. However, many challenges have to be managed before fast FSW will play out its advantage on large component assembly like the fuselage, mainly on affordable manufacturing tooling and corrosion resistance.

**Major technology streams**

- Investigating the possibilities of utilizing automated metal structures assembling in low volume production;
- Optimization of Friction Stir Welding and Friction Stir Spot Welding technologies for specific structural parts
- Advanced technologies in jigs/fixtures in utilization of prototype/serial production
- Alternative joining methods and cost-effective combination of metallic and composite structures
- Free fasteners joining technologies for metallic structures
- Advanced production technologies
- Application of integral structure concept
- Application of additive manufacturing parts

**Demonstration activities**

- Ground technological demonstrator presenting automated metal structures assembling, validation of used technologies;
- Airframe parts and subassemblies demonstrating advanced production processes and technologies, production hardware (jigs/tools) and processes itself, strength and fatigue tests;
- Static testing of Floats aircraft structure manufactured in hybrid materials leading to TRL level 5-6 validation.

The aim of small aircraft industry in the Airframe ITD is to reach technology maturity, according to the Technology Readiness Level methodology of TRL6, meaning that an airframe structure including fuselage, wing, secondary structures, jigs & tools will be demonstrated in a large scale project as a ground demonstrator (TRL6) in a relevant environment on ground.

**Tentative planning**

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**V. Advanced integration of systems in small a/c - WP B 3.5**

Small aircraft systems are different from large aircraft systems due to ultimate need for low weight, small dimensions, low cost and the severity to achieve these requirements on small dimension equipment together with reliability and performance.

Goal of this WP is to integrate in structure of small aircraft systems and technologies developed in ITD Systems in WP’s S.1 – S.5. Advanced system technologies are focused on reduction of the Operational Costs, improved cabin (noise, thermal, entertainment) & flight comfort and safety and security.

**Demonstration activities**

Demonstration activities will be based on the achievements of particular WPs of the ITD of Systems, namely:

- WP S.1 - Efficient operation of small aircraft with affordable health monitoring systems
- WP S.2 - More electric/electronic technologies for small aircraft
- WP S.3 - Fly-by-wire architecture for small aircraft
- WP S.4 - Affordable SESAR operation, modern cockpit and avionic solutions for small a/c
- WP S.5 - Comfortable and safe cabin for small aircraft

Tentative planning is provided in SAT ITD Systems WPs description, see Chapter 12.4.3.
WP S.1 - Efficient operation of small aircraft with affordable health monitoring systems

Onboard health monitoring technologies addressed in WP S.1 for SAT aircraft will be developed and demonstrated on selected A/C components and ground demonstrators. The expected target TRL for on board health monitoring technologies developed in this WP is 5/6.

WP S.2 - More electric/electronic technologies for small aircraft

More Electric/electronic technologies addressed in WP S.2 for SAT aircraft will be integrated and tested on aircraft platforms. The expected target TRL for more electronic/electric technologies developed in this WP is 5/6.

WP S.3 - Fly-by-wire architecture for small aircraft

The demonstrations of FBW for small aircraft will be organized in layered way. Three layers of demonstrations will be performed which will demonstrate different capabilities / functionalities of FBW starting on FBW module level, then on aircraft level and finally on air transport level:

- Demonstration of a representative FBW configuration for small aircraft on an iron bird stimulated by a closed loop simulator:
  - Cost efficient high reliable FBW modules (computing, input-output, actuators, power distribution);
  - FBW redundancy management;
  - FBW network communication;
  - FBW mechanical retrofit modules for easy aircraft integration.

- Demonstration of basic FBW functionality during flight tests on a small aircraft (increased safety by flight envelop protection):
  - Manual flight with digital stick / lever;
  - Auto pilot / Automatic flight;
  - Automatic take-off and landing.

- Demonstration of integration of FBW functionality in highly automated ATC/ATM environment during flight tests on a small aircraft (increase of safety by airspace violation avoidance, integration into SESAR):
  - Manual flight with easy handling characteristics;
  - Automatic execution of 4D SESAR business trajectories;
  - Emergency safe return.

In parallel guidance material for FBW development, certification, and operations will be prepared together with CAAs which will allow extending CS23 to FBW operations (similar as done for CS25 in the past).
WP 5.4 - Affordable SESAR operation, modern cockpit and avionic solutions for small a/c

- Affordable SESAR operation, modern cockpit and avionic solutions for small a/c will be demonstrated on System Integrated Lab with implemented new Glass Cockpit as well as some solutions will present on real platform.
- Laboratory tests and tests on real aircraft platform (ground and in flight) for affordable SESAR operation, modern cockpit and avionic solutions for small a/c technologies developed in this WP shall be estimated at TRL levels 4-6.

WP 5.5 - Comfortable and safe cabin for small aircraft

WP will be demonstrated on:

- Multifunction thermo-acoustic insulation of the cabin together with will smart passive damping devices and noise active control system reducing significantly vibration and noise in the fuselage structures and decreasing energetic needs of the cabin;
- Passenger individual comfort ensured by appropriate management of cabin airflow and temperature using innovative analytical approaches, low-energy ECS air distribution and recuperation, control of air quality during flight and operation from unprepared airstrips (separators, filters, air quality monitoring);
- New generation of lightweight comfort crashworthy seats in slim configuration adaptable to different requirements of airframers (seat track pitch, floor/wall mounts, padding shapes, IFE systems, hand luggage storage).

Coupon, stand and dynamic tests are planned in the course of development; results will be integrated into an aircraft demonstrator at TLR 5-6 and tested in flight.
12.4.2 ITD Engines
(Small Aircraft Engine Demonstrator – WP7, ref. to chapter. 10.7.7)

a) WP E.1 Reliable and more efficient operation of small turbine engines (19 seats)

The mission of the Engine ITD WPE.1 is to develop leading edge technologies specifically useful for next generation durable and efficient small turboprop engines for the business and general aviation markets (such as reference 19 seat aircraft). The Engine ITD WPE.1 will also include ground demonstration of these technologies utilizing a baseline certified engine model in order to minimize program costs not associated specifically with the technology improvements.

The improvement of fuel efficiency, the extension of service life between overhauls and the reduction of noise footprint will be the main drivers for the WPE.1 technology maturation plan and engine demonstration strategy. Specific attention will be paid to technologies able to increase the competitiveness of the European industry in the small turboprop gas turbine engine sector, so far dominated by non-European companies.

The design, development and ground demonstration of the innovative small turboprop propulsive system shall be rooted in an existing certified engine with high number of flight hours recorded and successful application of the spiral development process, in which selected technologies were developed and applied into the predecessor engine in order to create a new engine with step change in performance. This baseline engine will set WPE.1 references for technology improvements and for results tracking and measurement.

The technology development efforts will be focused on those areas that have a clear market application in the small turboprop segment, supporting the process of industrial revitalization in the European small turboprop engine sector, resulting in secured orders on new applications and exports outside of EU.

The gas turbine technology has established the dominance in the aircraft propulsion application due to high power to weight ratio and reliability, but its relatively high cost becomes very relevant when the power level decreases for the small aircraft application (< 1000kW). Advanced technology in gas turbines of the recent years has concentrated on large engines with a big impact on improving aviation transport efficiency and greening but only a little effort has been made on small gas turbines. The small gas turbine engine is distinguished from large power engine not so much in terms of overall requirements (reliability, relative lower specific fuel consumption etc.) , but rather in the severity of problems associated to achieve these requirements in small dimensions of various engine components and at a cost that will be economically successful in this market. As a result, technology development in this context requires design and manufacturing process innovation focused on increasing efficiency in this product size and at the required market costs. It is clear that without technology
innovation focused on improvement in small engine components design, material and manufacturing this high level target cannot be obtained.

The proposed work package will address technical challenges to deliver next generation turboprop engines for SAT aircraft, proposing step-changes from current state of the art and will deliver important improvements in engine technology, contributing to ACARE SRA goals achievements as set for 2020.

The Horizon2020 challenges will be addressed by taking the following actions:

- **toward “Creating resource efficient transport that respects the environment”**
  - Sub-system technology development delivering individual improvements in component efficiencies and contributing to the overall system enhancement for fuel efficiency improvement and noise reduction;
  - TRL incremental progression through design studies and rig tests to explore the technologies under development and their interactions up to TRL 6;
  - Setting a first step towards the goals for 2035 on the way to Flightpath2050, with TRL4-5 advanced technology stream for SAT turboprop long term innovation

- **toward “Building industrial leadership in Europe”**
  - Maintain and strengthen European competitiveness in Small Air Transport turboprop engines market by means of engine major evolutions; developing design and manufacturing technologies with application in both spiral development programs as well as new engine architectures.
  - Organisation of an integrated collaborative European partnership for SAT turboprops with the participation of key specialist companies and research organisations. Opportunities to participate will be offered through Calls for Core Partners and Call for Proposal structure of Clean Sky 2. The result of these efforts will be to build the technical capability of the partners in order to revitalize the turboprop design and manufacturing capability in Europe with the ability to compete more effectively with non-European entities.

WPE.1 plan will be focused on design, development and ground testing of a new demonstrator reaching TRL6 to validate key technologies to reduce fuel consumption and noise emission. WPE.1 will be mainly focused on High Pressure Turbine and Power Turbine efficiency improvement, combustor cooling optimisation and low noise propeller system (reduction gearbox and low noise propellers with integrated control system). In addition, specific attention will be dedicated to develop technologies able to reduce total

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<td>- Up to 15% of fuel efficiency improvement vs 2014 reference engine</td>
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<td>- Up to 10% of reduction of total operating costs vs 2014 reference engine</td>
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<td>- Contribute to noise reduction including propeller of 10 db</td>
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<th>Competitiveness objectives are:</th>
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<td>- Maintain and strengthen European competitiveness in Small Air Transport turboprop engines market</td>
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operating costs through the effective use of additive technology manufacturing methods for SAT market, precision casting, and efficient production technologies for critical engine parts, surface and heat treatment processes.

The work package will be enabled by the following contributing technology streams:

- **High performance gas generator.** This will be oriented to advanced technologies aiming at increasing turbine inlet temperature, core pressure ratio and consequently engine thermal efficiency. It shall include the introduction of high temperature materials, high efficiency turbine design, low pressure air bleed system, advanced combustor cooling. Benefits derived from the introduction of these new technologies shall be demonstrated at sub-system level and ground engine demonstration (TRL6) for performance and operability evaluation;

- **Enhanced power turbine** through advanced 3D aero-thermal design and advanced mechanical design solutions with the aim at increasing high altitude power turbine efficiency. The technology benefits will be demonstrated through ground engine test (TRL 6);

- **Reduction gearbox and low noise propellers with integrated control system.** This will include advanced materials, gears and bearings design solutions for RGB weight and cost reduction along with the development of low-noise propellers features with integrated control system with the goal to contribute to the SAT high level targets in terms of noise reduction. It will be demonstrated at sub-system level as well as ground engine test level (TRL 6).

- **Beyond-2020 technology preliminary validation.** This technology stream will contribute to technology assessment and preliminary development towards the goals beyond 2020 taking into account high level targets set in Flightpath 2050. It will be focused on design studies and sub-system validation tests (up to TRL 4-5) for long term SAT turboprop applications (2030).

Each stream will contribute to the high level objectives as the following:

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The activities in 2015 will mainly consist in optimizing the technology development and demonstration plan for WPE.1 small turboprop, leading to the definition of specific objectives and requirements for propulsion system and related components.

In addition, as required from the expert panel’s review of 2013, the engine targets (fuel consumption reduction, TBO improvements, noise reduction, etc.) and requirements will be further assessed against potential Core Partners technology proposal, refining and detailing the overall activity plan to be carried out within SAT Clean
Sky 2 frame. Specific attention will be dedicated to properly integrate the Engine and Airframe ITD’s work plans, applying highly developed management processes to straightening the focus on overall SAT high level objectives, ensuring effective coordination of activities and that technology development has a clear path to future market opportunities.

As far as the early phase of the program is concerned, the engine targets, the technology development plan and the detailed work plan will be revised and frozen amongst the selected partners as a reference for the following activities by the first quarter of 2015. The technology development activities for the engine sub-systems will start consequently.

The overall schedule for Engine ITD is the following:

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- **Airframer requirements**

**Current Situation**: Airframers require diesel engines as an alternative both to existing piston engines burning AVGAS 100LL and to small turbines. The diesel engines can solve the next points:
- **Availability:** AVGAS 100LL is not or rarely available on most promising emerging markets (Africa, Russia, China, India, South America),
- **Cost:** when AVGAS 100LL is available, excepted in the USA where the difference is small, the price is from twice the Jet fuels in Europe and can be over four times in some area in the world.
- **Safety:** the AVGAS 100LL is a gasoline based fuel, thus very flammable compared to the Jet fuels,
- **Environmental:** AVGAS 100LL is a leaded fuel, so estimating the shrinking world reserves of lead and also the negative impacts on the air quality, its future is not bright.

Smaller turbines (burning Jet fuels) are not a realistic alternative without further development because of limitations as:
- Higher carried fuel, as a small turbine fuel burn is much higher than the piston engine one,
- Higher purchase price of currently available turbine power units,
- Higher complex installation and maintenance requirements.

**Compression Ignition Solution**

The “compression ignition” engines burning the aeronautical kerosene/Jet fuels, otherwise called “diesel” engines, can reduce fuel burn by 50% to 65% compared to a small turbine engine, and by 30% to 50% compared with an avgas engine. These points bring both an environmental benefit and a drastic reduction of operating costs. Replacement of an Avgas piston engine by a diesel engine brings a high cumulative benefit of fuel burn and fuel price reduction.

On the first generation of diesel engines, the weight penalties were, for a medium range mission, more or less compensated by the fuel weight savings, but with the new high power density diesel engines, the global weight balance can be favourable to diesel versus avgas engines, even for short flight legs. Thus, it provides an additional benefit of payload for a medium range mission. A similar conclusion is obtained when new diesel engines and turbines are compared. There are also additional benefits for the diesel engines as:

- The lower speed of rotation allowing important noise reduction, both inside (in the cabin) for passengers and pilots comfort, and outside for the community. This last point may allow the survival of airfields near cities and by consequence the development of the SAT market.
- Reduction of the number of levers (no mixture) for a simpler control by the pilot,
- Reduction of inspection and maintenance (no magnetos, no sparks igniters ...)
- Etc.

Thus, the use of piston engines burning the affordable and worldwide available Kerosene fuel is a logical step to overcome these drawbacks. Airframers producing small airplanes create strong pressure to engine manufacturers to get their compression ignition power units more mature and certified with high performance.

- **Engine specifications**

**Aeronautical Design Intent**

SMA and SAT leaders are convinced to the need to propose to the SAT market diesel engines designed for the aeronautical use instead of conversion from automotive engines.
Indeed, existing automotive diesel engines have drawbacks. For example, they are not designed:

- To cruise at 75% of max power and to be significantly used at 100% for take-off or climb, while an automotive engine is most of the time at 30% of max power and rarely over,
- To run in altitude, eg. as high as 20,000 ft / 6000 m,
- To use kerosene fuel, but designed for the automotive diesel (not an aeronautical fuel),
- To drive a propeller, but designed to drive a automotive gear box,
- To be as light as the aviation market requires it,
- To be as thin as possible in order to be wing mounted,
- To take the benefit of a direct air cooling possibility,
- To comply the CS-23 certification rule (eg. ECU), but designed with additional constraints to meet the automotive certification rules,
- For the aviation long life market. The fast automotive market renewal strongly impacts the spare parts availability. The airworthiness management may be more difficult due to the automotive configuration management not really adapted for aviation.

Thus, the light weight engines have to be designed and optimized for the aeronautical use.

- **SAT ORIENTATIONS**

SAT leaders analyze that the benefit for the community will be higher if the project is oriented towards a professional use, typically for a twin engine commuter application, participating to the development of communication and transportation between European small and medium cities.

SAT aircraft manufacturers will specify Top Level Requirements of future Diesel power unit at the beginning of the WP, and later are ready to demonstrate the new engine on the flying platform. The current range of power may be capable to power aircraft from 4 to 9 passengers, perhaps more. Later, higher power rating may be requested, capable to power bigger aircraft, maybe up to 19 passengers.

Once the power unit is ready for installation, the WP will proceed to the demonstration phase. The most suitable platform will be selected in “Call for Proposal” or among the Leaders/Core Partners.

The power plant, including the engine and the propeller, should be optimized. The propeller design or adaptation will be selected in “Call for Proposal”. Synergies with ITD Engine WP3 will be considered, if any.

Synergies with development of CS1 Diesel engine (GRC4) Core engine design will be considered. Note: The CS1 is a race automotive derivative, having potentially the drawbacks as listed in §2 of such a derivative for GA application. In addition, CS1 developments have been done in the rotorcraft context.
**Demonstrators & Objectives**

**Recent achievements:** As a CS2 leader, SAFRAN through its SMA subsidiary certified and produce such power units for general aviation market in the range of 4 to 5 seats, and has a long term program of development.

On April 3rd, 2014, a scale-up of certified technologies in the 400 hp class successfully performed its first rotation.

**WP E.3 Reference Engine**

The 4 cylinder SR305 is the reference engine to perform coming evaluations.

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*SR305 certified engine*

- This engine is certified at 230 hp,
- This engine is in production and largely available for testing (many engines may be dedicated for the tests),
- This engine is mounted on two flight test beds, and may be used for some flight tests...
Additional demonstrators

In addition to demonstration on the reference engine, the SR460, a 6 cylinder engine, may be used for:

- Special demonstration for example for the dedicated fuel pump,
- On wing installation studies,
- Twin engine aircraft flight demo to address the “European commuter development”.

These two power units may be a base for future development and demonstrations, but it is not limited to them.

Objectives

The improvements will address several targets:

- The power density. It means power increase and weight reduction.
  - Power: +20% @ take-off, SL ISA +10% for cruise @ 10,000 ft
- Weight: -10%
  - Specific Fuel Consumption : 215 g/kWh in a large power range
- Powerplant Noise: -3 dB at least for cruise
  
  Note 1: should be measured in flight.
  
  Note 2: The reference engine is already more than 3 dB below regular engines.
- Durability: 2400 hr TBO
  
  Note: Demonstrated by design and stress tests, ideally by endurance tests.
- Cost: Significant reduction (confidential figures)

A TRL 6 or 7 is expected for each of new technology after the Clean Sky demonstration. The technologies involved should be compliant with CS-23 certification requirements.

Road map

- Field of work

  The studies will include not only the engine itself, but also the propeller and the on wing installation in order to optimize the powerplant system integrated in the aircraft. The field of work has been divided in 5 sub-work packages.
SUB WP AND TENTATIVE PLANNING

The tentative planning is detailed for each sub-work package.

MATERIALS, DESIGN AND MANUFACTURING

This work package addresses:

- Cylinder and cylinder head cooling improvement to allow higher power ratings and to meet the durability target (TRL 2),
- Heavy parts weight reduction without negative impact on durability (TRL 2),
- Manufacturing cost reduction (TRL 2),
- REACH application (TRL 3).

The design and material change should be the classic way to achieve these points. The manufacturing process and the control specification optimization should be additional levers to reduce the manufacturing cost.

Tentative Planning:

- 2014 Q3: Calls for Partners,
- 2015 Q1: Partners Selections,
- 2015: analysis, design, and manufacturing initiation,
- 2016: manufacturing completion and integration of the prototype parts in an engine,
- 2016: validation by demonstration in a test cell.
A second stage may take place afterwards.

PERFORMANCE AND OPERABILITY
Three technologies included in this package 3 items:

- The **turbocharger** system to provide more power in higher altitude (TRL 4). Performance, durability and costs are the main drivers.

- The **injection** system adapted for Jet fuel use in the general aviation context (TRL 4), Durability through the lubrication characteristic and Operability/Performance through the combustion quality are the main drivers. Indeed, Jet fuels are different from automotive diesel fuels.

- The engine management and protection w/ and w/out the **ECU** (Electronic Control Unit) system (TRL 3), A dedicated ECU adapted for the general aviation market should be developed.

Tentative Planning similar for the above 3 items:
- 2014 Q3: Call for Partner,
- 2015 Q1: Partner Selection,
- 2015: development of the solution, rig tests,
- 2016: test cell engine demonstration,
- 2016: in flight demo (SMA experimental single engine aircraft).

PROPPELER AND POWERPLANT

The **propeller**: The propeller is a significant part of a powerplant (TRL 3). Significant improvement should be done on the propeller:

- Durability without a significant weight impact:
  - For higher diesel torque,
For FOD and erosion resistance,
- Performance (Thrust & SFC) at low speed of rotation,
- Noise at low speed of rotation,
- Cost affordable for the GA market,
- Capable of feathering versions.

The propeller is very dependant to the engine and has to be treated as a powerplant system. Some action may include the engine dynamic.

**The powerplant management:**
A pitch control may allow additional speed of rotation reduction in flight leading to an additional noise and operability improvement (TRL 3).

**Tentative Planning:**
- 2014 Q3: Call for Partner,
- 2015 Q1: Partner Selection,
- 2015: Existing propeller tested on ground for a status (on SR305 and/or SR460),
- 2015: Development of propeller modifications,
- 2016: Modified propeller tested on ground,
- 2016: in flight demo (SMA experimental single engine aircraft). In order to establish noise, operability and performance improvements.

Later: step if requested as a fully new propeller.

**ALTERNATIVE ARCHITECTURES**
In addition to improvement of the SR305/SR460 technology, ground breaking technologies should be tested in parallel and improved. Two technologies have been identified:

- Two stroke engines: It should allow power density improvements (TRL 4).
- Hybrid engines: It should allow efficiency and noise improvements (TRL 2).

**Tentative Planning (disconnected from the other sub-WP):**
- 2014 Q3: Call for Partner (for two stroke option)
- 2015 Q1: Partner Selection,
- 2015: Initial demonstrator modification
- 2016: Test cell demonstration.
- 2016/2017: A second step may be proposed.
- TBD: Hybrid

**ON WING INSTALLATION**
The integration of the engine is key point of the success. Indeed a good installation of the engine and its accessories can provide weight reduction, a better compactness and a better efficiency of coolers. It allows a drag reduction. In fine, thrust and SFC are improved (TRL 3).

**Tentative Planning (taking into account the other WP schedules):**
- 2014 Q3 : Call for Partner
- 2014 Q4: Specifications provided by Evektor (SAT aircraft leader) to initiate the work,
- 2015 Q1 : Partner Selection 1Q 2015,
- 2015: Aircraft specification included in the engine design,
- 2015: Aircraft specification included in the engine installation, and digital mock-up,
- 2016: A ground demo of on wing installation (physical installation),
- 2017: A twin engine flight demonstration integrating all the improvement validated in the other sub-work packages.

Afterwards: second steps may be possible.

### 12.4.3 ITD Systems

(Small Aircraft Engine Demonstrator – WP7, ref. to chapter. 11.7)

The SAT program objective within this ITD is to research and develop the application of new and cost effective technologies in the area of systems for a future new generation small transport aircraft. The main target is to achieve the high level objectives:

- Reduction of the Operational Costs
- Reduction of Total Maintenance Cost
- Improved Cabin (noise, Thermal , entertainment) & Flight comfort;
- Safety and Security.

I. **WP S.1 Efficient operation of small aircraft with affordable health monitoring systems**

The major objective of the work package is to address efficient operation of small aircraft with affordable health monitoring systems by providing technology and knowledge for development of local diagnostic units for selected aircraft systems/components (e.g. Horizontal Stabilizer Trim Actuator, Landing Gear Actuator, etc.) as a part of an “Integrated Vehicle Health Management” (IVHM) system for small aircraft category.

Aircraft manufacturers and aircraft maintenance organizations have been long seeking for an advanced aircraft maintenance system.

Currently industry follows maintenance policy based on manufacturer’s guidelines for preventive maintenance intervals (i.e. remove and replace a certain part every given number of hours). During the last 10-15 years, the notion of “Condition Based Maintenance” (CBM) emerged and gained recognition as “maintenance policy”, which triggered industry to optimized preventive maintenance intervals according to specific conditions/symptoms/failure modes. The CBM is currently the state-of-the-art in the aviation industry (as well as other industries).

The next step innovation is based on methodology of Prognostic Health Management, which goes beyond the above mentioned state of the art (hence beyond CBM). The main difference between CBM (condition based maintenance) and PHM (prognostic health management) is the PHM’s capability of correlating numerous
conditions occurring in aircraft systems in order to predict the Remaining Useful Life (RUL) of the system under control, thus triggering preventive maintenance activity. The key element to achieve this high level objective is to have an enhanced health monitoring system by adjusting the hardware (sensor types, sensors’ topology and position) and data analysis methods to the selected equipment type of failure.

Affordable health monitoring systems reduce DOC costs of aircraft operation and directly contribute to the better competitiveness of such aircraft. Reduction of the small aircraft Total operative cost of 9% is expected (50% reduction of total maintenance cost).

**Major technology streams:**

- Local diagnostic and prognostic capabilities for selected small aircraft systems/components. Preliminary selection of components includes:
  - Advanced sensor system for structures (PZT, fiber optics)
  - Advanced sensor system for components (actuators, landing gear, hydraulic system ...)
  - Sensor signal processing, diagnostic and prognostic algorithms
- IVHM modular platform (interfaces, connectivity, local diagnostic units, CMC, standards) for small aircraft using a platform for IVHM, which will be developed as a part of other Clean Sky 2 ITDs respectively IADPs.

**Demonstration activities**

Demonstration activities of this WP will be part of WP 3.4 Advanced integration of systems in small a/c in ITD Airframe.

**Tentative planning**

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II. **WP 5.2 More electric/electronic technologies for small aircraft**

The Primary objective of this WP is to address the more electric/electronic technologies for small aircraft by providing technology and knowledge necessary to demonstrate the

- High Voltage generation & distribution and batteries,
- Low Power de-icing System,
- EMA for landing gear and braking by wire.

Aircraft electrical power consumption has increased dramatically in recent years. Technological advancements have led to the replacement of traditional hydraulic and pneumatic systems with electrically powered devices. In addition, new functions for small aircraft such as digital fly control system, electrical landing gear, de/anti-icing
and entertainment systems have been added, which further increases the demand for electrical power. As power needs increase, voltage or current, or both, must be increased. Increased current can be the least desirable result as it leads to larger and heavier wires. To mitigate the issue of wire weight and distribution losses, the latest “More Electric Aircraft” due also to a significant amount of existing electrical aircraft equipment (actuators, pumps, etc.) have been designed to use 270 V dc power. Increasing use of electrical power is seen as the direction of technological opportunity for aircraft power systems based on rapidly evolving advancements in power electronics with fault tolerant power distribution systems and efficient power management.

Integration of more electric/electric technologies brings better aircraft performance, DOC reduction, weight/fuel saving and increasing aircraft safety and operational envelope (e.g. de-icing system). Low cost systems solutions may be exported beyond Europe and increase competitiveness of European supply chain.
**Major technology streams**

- **High Voltage Generation/Distribution** - High Voltage Generator, Primary and Secondary Solid State Power Distribution and Management with Advanced Functionality; Scalable Power Electronics - inverters, converters, motor controllers
- **Low Power De-Icing System** - Low Power De-Icing System based on electro expulsive technology compatible with small aircraft limited space envelope availability and low weight requirements;
- **EMA** - Compact and lightweight Electromechanical Actuator for Landing Gear; Electric Braking
- **Batteries** - Focus on scalable safe Li-Ion Battery system compatible with low weight, low cost and limited space envelope requirements of small aircraft.

**Tentative planning**

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**Demonstration activities**

Demonstration activities of this WP will be part of WP 3.4 Advanced integration of systems in small a/c in ITD Airframe.
III. WP 5.3 Fly-by-wire architecture for small aircraft

In order to allow wide social acceptance of small aircraft as transportation means, also acquiring relevant market position, the careful consideration of safety and comfort issues is very relevant.

Safety has to be considered more and more a relevant issue in the project, due to the need of allowing regular people, not provided with high piloting skills, to pilot the aircraft while assuring safety levels not lower than the required ones or even higher. To achieve this result, very relevant effort has to be devoted to provide the vehicle with extensive flight automation capabilities in order to support the pilot in command or even to completely substitute him/her in some nominal conditions and in emergency situations requiring high skill to be managed. The achievement of this required level of safety through automation calls for the implementation of some of the most recent and innovative technologies used in the UAV framework on board of small aircraft. Nevertheless, a “simple” technology transfer from UAV to small aviation is not possible, due not only to technical reasons but mainly to target level of safety of large aircraft and at the same time affordable for the application on small aircraft vehicles.

Cost effective fly-by-wire system for small aircraft significantly increases aircraft safety by decreasing of pilot loads, what is important safety issue for small passenger and cargo aircraft. Low cost systems solutions may be exported beyond Europe and increase competitiveness of European supply chain.

Major technology streams

- Scalable high reliable but cost efficient FBW architecture;
- Easy handling characteristics;
- Automated flight including take-off and landing.

![Illustrative diagram of fly-by-wire concept](image)

RESULT: Fulfillment of Safety Target

Demonstration activities

Demonstration activities of this WP will be part of WP 3.4 Advanced integration of systems in small a/c in ITD Airframe.
Tentative planning

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IV. WP S.4 Affordable SESAR operation, modern cockpit and avionic solutions for small aircraft

Goal of this WP is developing universal cockpit which allows effective operation of commuter airplanes dependant on the user needs:

- Single pilot operations for commercial Cargo and Passenger (up to 9 passengers – current regulations);
- Dual pilot operations for commercial passenger transport (10 or more passengers);
- Single pilot operations for Cargo and Passenger (for 10 or more after increasing and proven safety level, pilot workload reduction and control systems enough to change regulations).

Major technology streams

The following technologies are planned to develop under WP S4:

- SAT avionic system architecture development for operation from remote and hub airports ("single pilot" for 9 PAX/19 PAX", low cost solutions)
- All weather solutions - strategic Wx, CVS/SVS – increasing autonomy,
- Safety & Surveillance solutions for SAT: Detection and Avoidance system,
- ATC datalink (affordable CPDLC);
- New control system technology for SAT: Smart Autopilot with flight envelope protection, remote control)
- SAT aircraft navigation (hybridized navigation, 4D navigation),
- SAT Multimodal cockpit - Increasing interaction and ergonomic level in cockpit and new interaction methods, pilot workload analysis, EFB/tablet applications (strategic, all phases of flight)
- Integration aspects for new SAT avionic components (Simulation methodology in preliminary stage of design of antenna location on the aircraft, RF susceptibility, EMC/EMI, HIRF  and Lightning protection,)

Application of affordable cockpit and avionic solutions significantly improve safety by decreasing pilot load. Detection and Avoidance system improves situational awareness in normal and emergency conditions. Low cost systems solutions may be exported beyond Europe and increase competitiveness of European supply chain.

Demonstration activities

Demonstration activities of this WP will be part of WP 3.4 Advanced integration of systems in small a/c in ITD Airframe.
V. WP S.5 Comfortable and safe cabin for small aircraft

The primary objective of this WP is to provide a step change in passenger comfort and safety during flight by providing the technology and knowledge needed to address the acoustic, air conditioning, air distribution, entertainment and crashworthiness issues specifically for small aircraft cabin.

The introduction of smart passive damping devices and noise active control system can reduce significantly vibration and noise in the fuselage structures; this together with multifunction thermo-acoustic cabin interior makes a package to improve cabin comfort focused on small aircraft issue.

Innovative ECS air distribution will address small aircraft cabin environmental control issue improving the passenger individual comfort by appropriate management of cabin airflow and temperature.

The last but not least improving passenger comfort is the IFE system tuned for this size of aircraft operations. Therefore, concepts and technologies will be developed and their proof of principle shown by simulation as well as hardware models in a most realistic test environment (including ground testing).

Aircraft with advanced cabin comfort will have a significant competitiveness advantage on the market and brings new export possibilities for European small aircraft industry and supply chain.

Major technology streams

- Green multifunctional insulation materials, low energy & low scrap production processes, recyclability; new materials/material structures combining multi-functionality (acoustic + thermal insulation + interior) will be developed and tested. Those materials have to have minimal environmental footprint during the whole live cycle and allow insulation vs. weight trade off. Multi-functionality of interior panels will incorporate possibility of radiation cabin heating.
- Active noise control devices tailored to different aeroplane noise sources (propeller, inner/outer aerodynamic noise); Development of active interior panels will be done and tested during flight.
- Verified analytical and measurement tools for prediction of acoustic environment during passive/active damping; Methodologies of advanced noise measurement (acoustic camera) and analytical tools will be developed and validated during the stand and flight tests.
- Personal comfort prediction tools; analytical tools evaluating passenger thermal, flow and acoustic comfort will be developed together with application of multidisciplinary optimization techniques ensuring maximum well-being on board.
- Advanced structural design of crashworthy configurable seats; For competent prediction/analysis of a dynamic behaviour of structure it is necessary to have dynamic material properties database that is not available for common aircraft materials. Till now no verified analytical method of seat dynamic test recognizable by airworthiness authorities does exist, only test can be used for proof of seat structures. Proved methodology developed in this WP will be presented to airworthiness authority to change this situation. Test starting from coupons up to full scale dynamic tests are planned to validate developed analytical tools.

**Demonstration activities**

Demonstration activities of this WP will be part of WP 3.4 Advanced integration of systems in small a/c in ITD Airframe.

**Tentative planning**

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13 Eco-Design

13.1 Going Beyond Clean Sky

Eco-Design is still a fresh avenue for an aeronautics contribution to the European Eco-Innovation agenda. It manifests itself in vertical and horizontal technology considerations that must be seeded upfront into technology pathways to reach meaningful broad effects, strengthened finally in top level integrated demonstrations. Integrated Demonstrators have strong potential in helping competitiveness, leadership and smart mobility. Eco-Design compliments this through a strong sustainability & socio-economic pillar in its activities.

Eco-Design has key materials, processes and resources impact and a strong relevance from the Flight Path 2050 and the expected HORIZON programme.

This goes well beyond full green recyclability and pristine life cycle guidance: Eco-Design serves as synergy and motivator for partnership in new business strengths, in the aeronautics manufacturing base of excellence, in new supply chain services interactions, advanced material cycles and opening synergies with the next innovative ITD/IADP technology streams that shouldn’t be missed.

To make all this happen, widely integrative-linked cooperation is essential. It is a logical next step to turn this successful ITD into a Transversal Activity.

The evolution of Eco-Design for Clean Sky 2

This chapter will first digress on the changes from the original to the new transversal activity which is more dimensional. It will point out its activity orientation, explaining the three delivery areas in the IADP/ITD interactions, and then finally capture in some detail typical Eco-Design work tasks.

The current Clean Sky set up is an Eco-Design ITD with two domains, one Eco-Design for Airframe and the other Eco-Design for Systems. A very short appreciation of this is given by the following captions of Eco-Design as it is now and then the perceived next upbringing for Clean Sky 2, ref. Figures 13.2 & 13.3.

Figure 13.1 –Present Eco-Design in Airframe and Systems Domain, Quick Look Caption
Eco-Design “Airframe” has an airframe focus with integration level interfaces, and a strong bottom-up approach that attracts a broad base of actors.

Eco-Design “Systems” is a strong performer in Clean Sky. In reducing non-renewable and noxious fluids including hydraulics, it addresses challenges arising from “hot impacts” from the all- or more electric a/c strategy. Eco-Design “Systems” yet should not be confused with any outright equipment development. This domain is limited to tasks operating as one address for ITD Systems, keeping the ecolonomic interface issues with a large Airframe ITD and IADPs.

This rationalizes Eco-Design to a focused activity on new eco-architectures and interfaces (on energy and other major footprints). This “correction” improves in return the Eco-Design delivery in systems, as well as in engines, substantially on materials, processes and resources (MPR). It allows broadening the exchange to large and small air transport with the focus on the ecolonomic architectures task.

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22 Successful, high TRL at Y2014 measurement, Eco Design developments with public grants will be of course exploited and carried forth in the next steps, e.g. the electrical bench, thermal bench, simulator concepts etc. serving an economic Clean Sky 2 Programme.
The outgoing Eco Design ITD will have established high TRL technology results with best athlete analyses, these contributions will be necessarily managed and exploited, c.f. “Expansion of 13.9 tables-part 2: Tentative Concept Reference, building on the results of Clean Sky with Eco Design ITD validated TRL at ES Y2014”

The TA will not duplicate the activity of technology readiness level (TRL) assessment which will be within ITD/IADPs responsibility; complementarily, the Eco-Design transversal activity is geared towards compliance on quality, repeatability etc. and recommendations for ecological and economic improvements. This also makes sense for instance on matters that have nothing to do with TRL but are an important concern for eco design, that are either compliant or not, e.g. reduction of REACH load.

In the following, an Eco Statements (ES) tableau highlights what the present Eco-Design Airframe project is about. Within Figure 13.4 statements can be found, based on a quantitative Life Cycle Analysis. The environmental key parameters, e.g. emissions or energy consumption, could be used to identify the processes of relevance (“hot spots”) of the considered parts and significantly influence the definition of a path towards a future aircraft system or technology. It shows also, which different aspects could be analysed to design a sustainable aircraft. E.g. for metals it could be useful to minimise the buy-to-fly- ratios, which results in less energy consumption for processing the metal and consequently less emissions.
Since only 2008, hundreds of partners and technologies have risen to these challenges but all in the confines of a small domain definition. A bigger transversal playing field is necessary and the opening to apply the technology from the lab through the integration to complete component application on aircraft level is essential.
13.2 Challenges to be tackled by Eco-Design in the Horizon 2020 Period

Eco-Design activity is well positioned to improve efficiencies, and to improve the material flow and logistics concerns, through a better view to suppliers, services and SMEs supporting these activities. That latter angle has strong requirement for Eco-Design to improve its socio-economic derivative impact.

![Diagram](image)

**Figure 13.5a – Further Improvement Scope on the one-dimensional, Open-Loop Product Life**

Looking to Figure 13.5a as strategy from year 2009, all the methodologies all align up to technologies, services and methodologies’ needs within a one-dimensional, sequential product life cycle impact.

Often technology spin-off is non-linear and Eco-Design must be capable of capturing a positive general effect. An example could be the last decades’ composites development. Some might say that high(est) gains have been achieved in the tooling development (precision, efficiency, special physics). How can this be better captured? There is no wide-base-strategy to contain and keep down the disadvantages of such an open loop process. Many aircraft will be withdrawn or converted from frontline duty; in parallel to quite high production expectations and replacement by low fuel aircraft (which *Clean Sky* is contributing to!). The extraction of materials, use of rare materials, coping competitively with high performance substitutes against other sectoral commodity demands will be a growing challenge.

For improving material flows, logistics and rare earth metals, it is essential to quantify material flows that are on the market and consequently can theoretically be used for a large scale application and further investigated after the end-of-life, if the material has been used and is stored in various products. The principle behind is the 1st law of thermodynamics on the conservation of matter meaning energy or mass is neither created nor destroyed by
any physical transformation processes. In order to enhance the appeal of increasing the implementation of secondary raw materials, robust logistics systems which meet the high quality and supply demands of their customers are needed, and the increased integration of dismantling plants and waste disposal companies into the supply chain structures of manufacturing companies. The aim of this is the paradigm shift, “From supply chain management to supply cycle management”

Beyond the data collection problem on the materials basis, it has to tackle the physical collection and distribution within improved material flow logic.

Regarding stakeholders, not only existing network structures of OEMS (value creator) have to be taken into account but also structures of global acting suppliers (facilitator), e.g. forwarders, and global acting customers, e.g. airlines.

Analysis and Evaluation of the supply chain has to consider structure and coordination of self-operating companies. With regard to inter organizational aspects between stakeholder and provider, new supply chain service interactions have to be achieved and some value added activities and support processes should be localized within the network in the future. The Inside-gate processes level, also including logistic and transport loads, shall have a more production integrated environment protection.

In all process levels and in the material life dimension, it is an aim to minimize the extraction and waste of resources, c.f. figures 13.5b&c.

As high alloyed and specific aviation tailored materials and to some extent rare earth metals are used, it becomes clear that their scarcity would put economic growth at risk. In addition, considering new legislations and restrictions (underlined by standards and regulations, e.g. the Sustainable Consumption and Production Action Plan (SCP) of the European Commission including the Communication on Integrated Product Policy (IPP), REACH etc.), the materials should be monitored within Eco-Design (develop a validated approach to determine environmental reasonable substitutions, classification and screening of essential materials for aviation, evaluation

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23 Compare various EU directives, which have also impacts on the aviation sector. The producers of electronic products face compliance questions with the regulations on “Waste Electrical and Electronic Equipment” (WEEE), “Restriction of the use of certain hazardous substances in electrical and electronic equipment” (RoHS) and “Energy using Products” (EuP).

24 REACH is the European Union regulation concerning the Registration, Evaluation, Authorisation & restriction of Chemicals.
of crucial influence and sensible substitution). This means Eco-Design in Clean Sky 2 is a consequent extension of the state-of-the-art LCA and supports Design for Compliance, Design for Environment, Design for Recycling and Design for Disassembly.

There is no easy melt-down and reemployment of aeronautics alloys and composites without substantial loss of performance: down-cycling through recycling is not a sustainable ecolonomic option. Full “Recycling Capability” as quoted in the 2050 flight path agenda will need a very broad but discerning approach in the Re-Use and End of Life scenarios.

The energy demand across all life cycle segments is not a trivial issue, the manufacturing and production phases are of particular concern. Other footprints such as water and waste treatment, effects on general ground pollution will be brought to the forefront in a more comprehensive life cycle screening. The present Eco-Design initiative has found major collaborative answers for anti-corrosion strategies, but Sulphur and Cadmium are still with us. A broad, long-term Eco-Design Clean Sky capacity could be used to get strong stakeholder acceptance and solutions e.g. for the substitution of potential hazardous substances and indirect water depletion in the aeronautics product chain. Clean Sky leadership on innovation to close the gaps on such matters should be insisted, as is being done on mission/use-phase fuel burn emissions. In the future, the control over material, processes, resources could improve significantly e.g. through controlled fragmentation, sorting down to molecular bias and a well organised logistic chain. That could be linked to direct-reformed and more authoritative and cooperative manufacturing. Maintenance, repair and overhaul is not so distinctly a separate life phase as depicted in Figure 13.5a, it will have a stronger incipient stage in the “materials” and manufacturing activities. This could mean for new technology pathways that all stakeholders must be encouraged to contribute to a new life cycle plus vision for 2020+, not just the immediate needs. A possible picture for a better closed-loop or more mobile loop is given in the following picture:

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25 Note that while the extraction and withdrawal phase are understood in the basic life cycle analysis(LCA) it is an aim to reduce these phases to a minimum, and consequently they are cancelled out of the idealistic pictorial 13.6
Some possible vision statements could be lightly tabulated as follows:

<table>
<thead>
<tr>
<th>Eco-Design for Environment (DfE), Horizon period</th>
<th>Eco-Design for Socio-Ecolonomics(^{26}) value 2050?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clean Sky 2</strong></td>
<td><strong>Clean Sky 2 paving the way</strong></td>
</tr>
<tr>
<td>▪ Design to Ecolonomic Footprint</td>
<td>▪ Recurring Life Value, where would the term</td>
</tr>
<tr>
<td>▪ High European differentiation in unprecedented quality and eco compliance for unparalleled competitiveness</td>
<td>obsolescence be in full RE-cycle?</td>
</tr>
<tr>
<td>▪ Reaching a Global Supply Chain Eco-Design understanding and vehicle platform gearing to Eco-Design architectures</td>
<td>▪ Free material (&amp; Processes) Optimisation for Life Cycle Value and use phase/mission performance [no restriction through sizing, topology or configuration]</td>
</tr>
<tr>
<td>▪ LCA driven technology definition and realization bestowed to new technology stream performance</td>
<td>▪ Free Socio-Ecolonomic Resourcing Optimization &amp; Exploitation</td>
</tr>
<tr>
<td>▪ Secure Ecological Deference Strategies, End Of Life Technology Minimized Elimination/Depletion of Resources</td>
<td>▪ CO(_2) capture and extraction through transversal, alternative sectorial and supply-cycle process bonding</td>
</tr>
<tr>
<td>▪ Down Cycling Reduction, technical and market strength gains through clean technologies, Eco compliant materials inferred processes’ performance stable on big scale integrations</td>
<td>▪ Introduction and feeding in of special research competences, special labs into the big picture impact.</td>
</tr>
<tr>
<td>▪ Continued transformation from supply chain to supply cycle management</td>
<td>▪ A strengthened new stem of aeronautical job qualification and stakeholder acceptance in this activity</td>
</tr>
<tr>
<td>▪ Game changing alternative application scoping through bio-chemical and high level physics approaches</td>
<td></td>
</tr>
</tbody>
</table>

\(^{26}\)“Ecolonomic” means to combine positively the impact of economical and ecological advantages.
13.3 Scope and Setup of Eco-Design

13.3.1 Eco-Design, its outlay in essential “sub-activities” and concept of delivery

Eco-Design follows a reference concept for its contributing technology pools in [Eco-Design Life and REcycle], reflecting themes from conventional and expanded product life phase approaches. These form the grid of items that fall into the practical research of the major sub-activities:

- Vehicle\textsuperscript{27} Ecological, Economic Synergy (VEES) activity- through the Eco-Design Work Units described in fig. 13.10
- Eco-Design Analysis (EDAS) activity and finally the Eco-Design Transversal Coordination described in fig. 13.17

First the concept of delivery levels will be explained then exemplarily the activities will be re-visited.

13.3.2 Eco-Design Interactions with IADPs and ITDs through its delivery levels

The Eco-Design activity has a baseline, mainline and top level delivery basis. This characterises the interactions with the ITD/IADP and through them the output to the TE.

I. Baseline

The baseline annotates the take-up of technologies from an eco-innovation angle for the benefit of improving ITD/IADP activities. The main duty for this stands out through the Eco-Design Life and REcycle reference which is an orientation for current and forward looking technology pools.

There will be a strong set of founding technologies from these technology pools. Yet, at least a third of the activity roots at 2014 should imply receiving totally new approaches, to ensure fresh technology alternatives are made available. This baseline can grow and develop continued improvement. Then, from around 2017/2018 second batch calls should competitively challenge the basis as the ITD/IADPs enter into the next technology waves responding to higher demonstrators’ TRL robustness.

Eco-Design on the other hand unifies specific clean technology and Eco-Design process improvement upon the technology streams. Thus, Eco-Design is fully complementary and integrative. The following diagram tries to explain this:

\textsuperscript{27} Includes Engine and Systems
Figure 13.7 – Eco-Design Processes in the Roadmap of Excellence

Figure 13.7 characterises also Eco Design’s typical interest in safekeeping of Materials, Processes and Resources (MPR) Interactions.

II. Mainline

The ‘mainline delivery’ is addressed by the coordinated orientation agreed with the ITD/IADP; obviously different vehicles and systems will have a different weighted approach depending on current developments. This is mostly accomplished by the selected Eco-Design work units into the ITD/IADP-WP-plot, supported by Eco-Design analysis.

Eco-Design needs real life technology ensembles, and is dependent on a concept to track complete processes, complete vehicles and complete architectures. This can be formed on building blocks (as accessible modules) from the perimeter of Eco-Design in the respective ITD/IADP. Eco-Design Analysis then validates the vehicle-level life cycle impact.
The agenda towards more environmentally friendly, more affordable vehicle systems will be exploited e.g. R/C life craft, MAMEF 28, zero global warming potential cabin & system demonstrations 29, various more environmentally friendly systems components (IMA, LG, across-ATA, etc.) and engine eco-MPR enabling pathways, and perhaps at the top end, a Global Environment empowered HUCCE (Human Centred Cabin Environment) contribution.

In 2014, these concepts will not be able to contain all the virtues of life cycle variables and will be working towards an optimum. A coordinated forward looking approach has to be found, combining best synergies to get the respective full air-vehicle picture, working with high performance issues.

Eco-Design purpose must break ground and depart in grand manner from the last decades’ attitude “Eco is (just) good for secondary structures and coupon lab exercises”. That will boost the researcher perspective into the big picture of integration Clean Sky has to offer.

Eco-Design will deliver an Eco Hybrid Platform (EHP) which is totally life cycle plus (LCA+) driven in its design. Furthermore, in the spirit of Horizon, a fully open access hardware & simulation resource and visible realisation will be available for the community. It also means the networking of RE-Cycle and Re-Use facilities so that one can appreciate what a whole modern partnership for eco-life may look like.

LCA+ is a life cycle analysis “plus” outcome is in view of a Design for Environment (DfE) vision which is still building itself!

Hybrid, in the context of eco design, implies the use of modules that within their definition segment constitute an ecolonomic 30 advance compared to 2014, with strong eco-compliance.

“Frame” is now an open definition for fuselage, wing or whole control surface which helps react to later strategic synergies in the Clean Sky 2 Programme.

In Clean Sky 2, Eco-Design should be supported to “check in and check out” every funded technology exercise with an LCA appraisal and recommendation- this is like keeping trace and recurring options afloat.

III. Top level

28 MAMEF is a re-occurring step forward philosophy for various demonstrator parts more affordable metal and competing composite frame or fuselage to the more affordable more environmentally friendly contingencies in manufacturing, depending on sharp production volume sensitivities, viable steps forward from the perspective of available technologies at 2014. Eco Design puts this acronym in front of more environmentally friendly vehicle („frame“) parts including the wing on its own, even it is „just“ lighter producing less drag on the vehicle, if really production and other life phases gain at least a relative ecological improvement.

29 ZGWP zero global warming potential fuselage, is something similar to the zero carbon footprint product w/o considering the chemical chain losses from the engine, but having such a total life cycle analysed ground pollution and resources including water deplet status. It shall be affordable. Thus it is a step beyond the MAMEF but requires considerable next generation technology interactions and eco-design architectures optimality.

30 This means both economical and ecological advances.
The top level delivery complements the Technology Evaluator analysis of the ITD/IADP benefits according to the global socio-economic demands. Generally, but not exclusively, this will be based on results in a big impact technology pathway (BITP) format which will be served also to the examination of industrialisation scoping of the ITD/ IADPs. The following schematic, fig. 13.8a, is a visualization of expected delivery paths in a grand prospectus.

**Legend for Figure 13.8 and delivery mapping caption:** MPR: Materials Processes and Resources, MPB: Major Physical Benches, VS: Virtual System, CM/PM: Component, Process Module, HFM HSM: Hybrid Frame or System Module, EHP Eco Hybrid Platform, SED: Socio-Economic Derivative, BITP: Big Impact Technology Pathway, VTM: Virtual Test Module, VA: Virtual Architecture.
Success Story Implementation ITD-ECO Design-IADP
Big Impact Technology Pathway (BITP)

Figure 13.8b – Big Impact Technology Pathway Example, Airframe-ECO TA-IADP starting with certain milling tool process which after modifications could be used for the cutting out/trimming of apertures, windows in the large carbon fibre component, further technologies can start another commonality access to other applications

**TE Delivery through the ITD/IADP**

The TE will be at hand to grasp the global outcomes of Clean Sky 2 advanced & innovative configurations from the ITD/ IADPs. From the Eco-Design point of view, the innovative configurations should reach the TE with the best integrated eco-compliance possible. On its monitoring of this satisfactory process, Eco-Design will collate and provide a step by step visualization of the Eco-Design compliant modules coming together to form a complete, but obviously “non-flying”, summary Hybrid Eco Vehicle(HEV). It is a sort of vision dissemination of the Eco Hybrid platform.

**Additionally, top down there will be pull through to the TE**

- To provide wide closure of Eco-Design activities regarding material flow and logistics. This is very different to any bill of processes or bill of materials approach practiced in the current Clean Sky program.
- To understand Eco-Design impact with clean technologies in labour value growth and flexibility through process improvement on two scalable levels, Work effort units (gain, remediation) in the BITP scenario, at a 100 man work force and secondly at a 1000 man work force abstraction.
To understand the relative-derivative on the BITP regarding LCA- and LCA+ outlook; this is only meaningful if a separate relevant IADP/ITD user benefit analysis is adjoined to it, e.g. through the coordinated quality function deployment, through built-on-facts, economic harmonisation.

To make out an appropriate socio-economic analytical derivate, including participatory-reviews, that should respect the peculiarities of the particular vehicle type and mission. (Eco-Design treats the production volume, depreciation, operator etc. wholly different between a small propeller a/c and a large jet transport a/c, NOT ATS, ATM issues etc.)

Later on in the Programme various supply chain scoping exercises should be carried out to solidify the impact assumptions, for instance, practically through networking incoming SME projects to provide impact data, and assert an outset individual socio-economic goal. Eco-Design Analysis will provide them with various tailored approaches. A transversal coordination will be put in place to follow up the Eco-Design delivery as in ref. figures 13.8a), b) and 13.9 below.

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**Figure 13.9 – Technical and Coordination Plateau of Eco-Design**
13.4 Work Breakdown Structure

13.4.1 Eco-Design Life & REcycle and some Eco-Design work units examples

An outlay is given for possible technology pool resources from themes that an Eco life cycle activity can relate to, fig. 13.10. Example (see below): T2EoL end of life technology exercise on one of the modules. This can stand on its own complimentarily or be attributed to any one or multiple WPs or technology streams in the ITD/IADP. Full traceability and flexibly will be achieved without having to reside only in one “WP Eco Design” or “WP Materials Processes, Resources”. There might be some multiple factoring which might lead to a participation contribution in one WP noted as for example: AirframeWP3.4 (T2ADS, T2EoL). A Feel for typical more general ECOTech technologies, characterisation in view of the Technology Streams is given in a selection of how project proposals would be sorted out. T2 are strongly characterised by the specifics of the demonstrator modules. Eco-Design deliberately avoids descriptions of preliminary, critical design terminology and refers simply to realisation.

![Eco Design Work Units, Eco Design Life & REcycle, Pert Diagram I](image_url)

**Use Phase [UP]** is the sum of operational utilization in flight time plus turn-around time (i.e. block time). This definition is brought in to separate out the Eco-Design activity outside the use phase, where for example the flight
physics, optimisation of mission performance is played. It is however important to receive the “loads” of the perceived utilization from the ITD/IADP to allow closed eco-scoping on different eco-compliant life propositions.

**Materials, Processes and Resources (MPR)** has as philosophy to avoid raw materials extraction, to learn and lead-in alternative modern resourcing methodologies. Aeronautics worthy materials, composites or alloys often only differ by 5% in constituents to their counterparts in commodity or general commercial applications, yet the performance specification, and from CS Eco-Design results, the life cycle process impacting are worlds apart. This is why it is key to monitor and build upon the general data base from current *Clean Sky* and attach this as well to a prominent general co-ordination activity [T0.2] on the next pert chart diagram II. The material base has to be applicable to aeronautics eco-compliant processes and aeronautics usage. The figure 13.11 below shows that the data bases structure concepts will be more differentiated. Conventional or smart materials, bio materials assumptions have to be kept up to date. As an example, deeply drawn/formed spotless steals with min gauge viable yield strengths in reach of 1500 to 2000N/mm² become reality, then there can be a tilting effect too on the Eco-Design ecolonomic recommendation, not only in performance for specific strength and stiffness criteria.

Another example story line in the essence of eco design materials development could be as follows:

In the development of green aircraft new materials will be developed for recyclability, fatigue resistance, weight reduction, corrosion resistance and resource efficiency. To guarantee a safe and ecolonomic long term use of the aircraft structure the development of green repair solutions is one example for technologies under development to increase material lifetime. These fast and low energy consuming heat and curing techniques are concerning near infrared and induction detection technologies to locate defect CFRP parts. In the area of microwave and plasma technology, an interdisciplinary team carries out research and development on microwave-based processes and technologies for the heating, drying, welding, bonding and joining of polymers. A recent topic is the rapid microwave curing of thermosets for composite production. An advanced microwave system for the direct heating of carbon-fibre-reinforced polymers is on top for the research, leading to a significant increase in economic efficiency, especially for large and thick-walled components for the aviation.

To bear out the beginnings of the new eco design, the rear of this chapter 13 has appended so-called story boards. Each are annotated with a “MPR strengthening” purpose. One might like to compare for instance such tentative project approaches as

- Anodizing goes *Clean Sky* 2
- Building on Clean Sky Success - Tartaseal
- Energy balance for production process of Al – MMC – Nanocarbons
- Wireless Autonomous SHM System (WISS)
- End of life bio recycling
- Building on *Clean Sky* Success, Bio-based flame retardants and raw materials for PU foams

MPR is not only a theme reference, also a working activity that involves general participatory actions like workshops coming from continued *Clean Sky* needs: to address an horizon of specific topics such as LCA, REACH, smart materials, auxiliary (manufacturing/treatment/additive..) materials, tools, logistics etc., answering a basic need to communicate on common difficulties/solutions, fast track IPR and usage benefit consultations. See the table represented in 13.11.
Furthermore the data base will harness in general the advanced material resources in Clean Sky. Not doing this would be a failure. E.g. some advanced metals have to be looked up not only for smart application but also for scarceness, competitive material flow bottlenecks.

<table>
<thead>
<tr>
<th>Materials, Processes and Resources (MPR) Accountability and Exploitation (Data Base Character)</th>
<th>2013 Avenue</th>
<th>Post 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMR Advanced Material Resources exploitation outstanding product category mapped, smart capabilities, essential environmental-operational loads development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOM Bill of Materials state of the art (simplified or expert follow up) state of the art (Life Information Technology /CAE? concept-origin)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOP Bill of Processes hierarchical process-depth impact; discerned footprint selection Integrated IPR strategies, intelligent hierarchy including auxiliary efforts. LCA+ handles, selectable cost variables/mutualization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCI Life Cycle Inventory European Norm Inference ongoing, compliance with aeronautics needs, more automatisation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BITP Big Impact Technology Pathway reference ensemble MPR chain, subjected to eco-life value impact and Industrialization scoping any intensive value derivative, paralleled to flying weight compliance, socio-economic derivative norm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 13.11 -Materials, Processes and Resources Accountability and Exploitation Data Bases

**Manufacture / Production [C]** hold key importance for Eco-Design application leverage. Lower resource consumption, waste and emission reduction and the increasing recyclability of components are the main objectives in developing new manufacturing technologies and improving existing ones. Important footprints come from primary energy consumption with an exacting view of the cost, also of renewable energy resources in the bill of processes. This is growing in concern to levels even of labour cost and impacts on efficiency and qualification. To avoid market failure, noticeably medium enterprises could be pushed to relocate out-side Europe to exploit cheaper but dirty energy cost. However, if EU companies and in particular SMEs can develop innovative manufacturing processes and strengthen firms’ capabilities, they will be in a strong position to respond to market and societal demands for improved environmental performance from the aviation industry. For certain, due to the importance of the manufacturing base, probably a third at least of the Eco-Design technology port-folio will be cited from this theme. Also environmental assessment (LCAs) will be conducted in parallel during the development processes to improve the environmental performance of innovative stages.
Inside the manufacture and production, leaning on clean and efficient technologies, a more coordinated *automation and assisted manual processes* could be designed and proven on a wider factory and supplier-(integrated) MRO scale.

One example of an enabler could be the exploitation of more *unmanned-automated* and more *independent-portable* fabrication processes. This is of course a case by case applicability and qualified process issue and a growing dependency on more forward thinking design. New technologies’ combination, like "out - of - autoclave" (OOA) prepreg and "liquid composite moulding" (LCM) technologies for suitable one-shot co-curing processes have been exemplified in the MPR section. The point of higher integration lowering energy consumption and facilitating hybrid structures was made. Their multiplication expands the concept of integrated structures. Hybrid processes enable the advantage of both technologies to be exploited in different components of a structure. Moreover, the higher integration reduces the manufacturing cycle time and the overall energy consumption of the manufacturing process. One of the key words will then be production adaptability using new modularity in the producer portfolio to create new return scenarios for their customers. A "simple" improvement is the classical but still very difficult parallelism of desynchronised development processes. This places high challenges on new tolerance architectures, freely looking forward and backwards capabilities in emerging solutions with artificial technological intelligence, beyond just virtual reality. To get any simplified or clarified ecological and economic design derivatives in here, probably not just a singular MPR portfolio is satisfactory in demonstration. At least two production cubicles would have to be over-sighted to get key value validation from the aspect of component(s) production. Such valuations could be targeted post 2017.

Beyond 2020, at each basic production unit, more ergonomic processes and robotics could be targeted for the component *inside-out* assembly where adaptive- and work load- or walk around assistance for the highly qualified labour is missing. Till then ecolonomic, leaner *outside-in* assembly and manufacturing will be considerably improved, using follow-on technologies to developed *Clean Sky* surface treatments and so on. Because Eco-Design is trying to reduce primary energy demand and to improve simple economic life leverages, there is nothing therefore against straight forward systematic solutions, like simply reducing the weight of tools or manufacturing units which would reduce energy and labour cost in moving them around, or simplification/adaptation of tool mounting intelligence. By the way, reduced manual loads in the sense of also improved lighter and cleaner working conditions would also be socio-economically evaluated. In *Clean Sky* 2 it is foreseen to go beyond established technology or advanced ones by contemplating the neighbouring steps. It is important for Eco-Design to appreciate the pre- and post-step link effort, e.g. in preparing the tool, in stripping off the work piece and so on.

The same sort of framework inspiration should flow to the various **Services to Components and Systems [D]** for hand-in-hand improvements. Typically, the growing market and also ecological impact of *maintenance, repair and...*
overhaul (MRO) is central, yet considerably more could be done to capture inside and outside gate process together. For instance, a silicon seal or mount is qualified for performance but there is also an essential factor of getting supply/delivery right with shelf life constraints and management costs. Various issues can be attached according to differing prominence in the various vehicle or system or engine view angle, say to limited life parts, original parts, components off-the-shelf (COTS) and so on. Airframe forms the bulk of a vehicle, still Eco-Design CS2 will pay widened orientation to different material and meso-mechanical orientation, specific MRO itinerary, more “learn-across” approaches to motivate more activity from Systems ITD as well as the Engines ITD. It has become apparent that also new financing and virtual-equipment/part-scenario training tools for these extensive inside processes are in need for development, to scope the economic effects or where to “fit in” or “climb up to” as a new service supplier.

At this stage two important terms must be discerned, one is ecolonomic and the other (structural etc.) health monitoring and coping with degradation at this technological theme review.

Ecolonomic can be assessed at machine level and then in conjunction with an all-comprising machine systems analysis and optimisation, this was attempted in the former Eco Design EDS. That can be related to the ownership scale of equipment or even an aircraft. The other ecolonomic angle comes from the bottom-up materials, processes and resources through production and other life phase values’ causeway.

Structural health monitoring (SHM) and managing degradation is a huge branch of concern in aeronautics. Based on the development of prognostic methods component lifetime can be increased or margin of safety better controlled, that is the difficult classical basics. The fundamental school, “just” on crack initiation, would expand on 1) structural context, 2) loading type with its topology, 3) the loading history, 4) surface disposition, 5) material and 6) the environmental conditions. This list hasn’t even the difference between laser beam welding and friction stir welding. Eco Design TA doesn’t map the necessary business as usual avenues. The technology readiness rationale together with a spirited component approach is with the ITD/ IADP. Eco Design will not try to populate S-N-curves but rather take the handling context further or expand on new breakthrough life philosophies, work reverse 6) to 4) in focus, without blandly expending the same invested approaches through FP6, FP7, instead expanding on what was already done, importantly also in Eco Design EDA. The TA will beckon entries that answer to manpower & service affordable solutions, strategies that are being inserted in the production and then on into the MRO life perspective.

Examples are given also in the story boards, and these are clearly susceptible to collaborative high AND low TRL research needs such as unknown signal to noise, power consumption, system nesting and physically effective packaging. If the basic school delimits a break-even point between structure and sensor life then eco design would radically require the economic production of sensorized structures rather than just the economic production of the sensors or structure separately. In a strife to gain more acceptance, the need-conversion is put upfront: Thus a Protection philosophy by need is headlined.

Protection converts the technologies which help to sustain the use of the component for a possible care free long life and/or storage strategy and other strategies such as sacrificial life (special release films, certain parts, tooling etc.) but in a way that the life information is suitable for the concern of the user. That means that not only a

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31 For example numerous EU projects TATEM, AISHA, TRIADE,…. including CS GRA LWC!
cross-over\textsuperscript{32} on say Wöhler curves is consulted but also on the information strategy and multi-functionality need. "Green" repair solutions (e.g. infrared and induction detection technologies) could then be adapted to guarantee an ecolonomic ownership. Similarly, fast ultrasonic, dielectric, electromagnetic and traceable technologies could be used to enhance green and safe in-production inserted capabilities, characteristically.

Eco-Design must handle big topics such as attrition and in-depth tribology research, corrosion with still a high defeating impact on any ecolonomic life assumption. State of the art corrosion treatments have been mentioned, advancement on which transversally all can profit from is needed. Such matters are coped with through wide scale [ECOTech] work units under the [T2] type tasks.

Through Clean Sky, a widened scale of End of Life [EoL] technology, as the inevitable matter of withdrawal, was introduced and will be continually improved; The objectives are focussed on recycling technologies including better material identification methods, optimized recycling and testing methods for carbon-fibre reinforced materials, improved recycling routes for metals and high-performance metal alloys instead of just the improvement of basic cutting and sorting technologies. There will be more physically selective methods encouraged, e.g. say electro-dynamic/static separation or impact treatment, if there is real user follow-on benefit at acceptable life cycle cost (water basis, energy demand etc.); as in every technology step, enough services and viable qualified labour resources scenarios have to be mapped out. Technical improvements in resource recovery (e.g. treatment of EoL paint, paint removal and resin removal and fibre recovering technologies, reuse applications for the recovered fibres in aerospace applications, env. management of waste & consumables) will be supported by network logistic solutions to ensure materials with low value or low proportions of weight (e.g. glass fibre composites, plastics, textiles) are kept in the system as well. By identification of potential parts from aircraft, rotocraft and engine and to define fields for their application, [Re-Use] will be set as first choice before recovering single material (or fractions) deployed in the parts. As the main focus of End of Life topics in Clean Sky was set on airframe material, the focus in Clean Sky 2 will be expended to avionic, engine and component (efficient end of life technologies through discussion and optimization of processes, logistic routes and design, e.g. sorting, optimize and treatment guidelines for metals, recovery and reuse of hybrid materials, fibre reinforced polymers (carbon, glass and aramid fibres), textiles etc.

Assembly, Disassembly and Separation [ADS] addresses an important Eco-Design area. Examples: If it is clearly a challenge to quality-mount a laminar or adaptive surface component, what is the disassembly prospectus for overhaul? Or also for smart materials, motors inside!

If everything were hybrid, how would you separate efficiently?
How would you unlock new Re-forming/adaptive capacities from manufacture? It is clear that separation must be purpose led and built in the design- of course without risk to reliability. Finally, purpose led fragmentation, molecular sorting could be key sign-post technologies to take care of a future more closed loop RE-use options, such as very-advanced direct manufacturing. It is not fanciful to contemplate a scenario, in which a hybrid L/E is taken off the wing, the plastic components are degenerated, biased and supplied to a special direct manufacturing fabrication of a complex ventilation piping inside the wing. Direct manufacturing (DM) by layer or monolithically, particle-, droplet- applied etc. could be an Eco-Design closed-loop enabler of the future.

\textsuperscript{32} At high cycle N count, beyond the cross-over, the SHM system itself may have ditched under the host material Wöhler curve, Miscellaneous concerns e.g. in Lehmann et al. Anforderungen an strukturintegrierte Überwachungssysteme, Proceedings, Congress Intelligente Leichtbausysteme, Hannover, Sept. 2006.
Would in 2020, near net shape or fully integrally (milled) assets be overtaken by new separation and formation capacities?

If one takes in part/system assembly Eco Design[ADS], concurrently with performance design of the ITD/IADP, one should target overall 60% cost and operational advantages, compared to competition positioning at Y2014, that will need an authoritative big technology pathway bill of processes, and “snow ball effect” synergies.

**Alternative Sectorial Applications [ASA]** are an important technological resource area, external evaluations have time and time again drawn Eco-Design attention to questions like how do automotive run up a bill of materials and processes in such a short time compared to aeronautics? Eco-Design has steered in innovative enabling aviation materials processes (from scrap high performance material) into the building environment to potentially reduce heavy CO₂ footprints there. Bio-Chemical processes amongst other alternative research potentials could be brought in as with special labs to investigate game changing rules; inversely, available natural glues could be developed for improved large scale and complex geometry application. In Eco-Design airframe, large cork implementations, as sandwich structure alternative, are being demonstrated. The list of ideas is completely open from the perspective of Eco Design.

**Next Generation Life Scoping and Information [A]**, this is the back-end but also the beginning of Eco-Design life. It is clear that an Eco-Design Life needs well thought identification strategies and obviously far reaching Life Information Technology (LIFT) strategies well beyond current RFID, built-in-test etc. approaches, yet not conflicting with SHM for innovative performance guidance. The Life has to be simple and not confusing for the user, like a consumer in other sectors, a concept not exploding in detail and interpretation if fidelity goes molecular? The part itself can inform perhaps better than the worker or the computer integrated manufacturing plant around it what has to happen next to it, in its tolerance in manufacturing, MRO? Is it ultimate Eol sorting? Can originality and non-erasable competiveness be built-in? Is that allowed to end up on the scrap heap? Eco-Design Analysis has a clear challenge in any modules management, and some of its problem alleviation could start here (identification, selection and data collection of new potentials of advanced aircraft technologies and materials, documentation of new process and technologies as well as upgrading the Eco-Design database for the Consortium partners).

![Figure 13.13 - Structure in different scenarios, major component, frame part, fragmented pieces](image)

**Eco Architectures [T3]**

Eco-Design will try to show a “light” but important information accrual across the vehicles of major footprints that need relevant transparency and prospectus balance, in comparison to the consumptions through the whole life cycle; not just in use-phase but also during the “rest” or so-called indirect phase.
Without impinging on the background or intrinsic foreground equipment and frame part developments it must be possible to deliver as user benefit a tableau of modules’ resource consumption as in product classifications seen in other sectors. Such a transparency across the programme should be followed up in CS2. It is also possible that new bio-mechanical architectures and human centred design or payload customization architectures have an edge or supporting reference for Eco Design! For brevity, only three impacts\(^a\) b) & c) are referenced here.

a. Normalized use phase water turn over and water consumption in non-use phase (or so-called indirect factor)
b. Relative water to air use

It is generally accepted that soon for instance the water footprint will have to be depicted/assessed separately for future ISO 140040-plus references (presently it is only weakly intrinsic in the other LCA factors)

c. Latent & Demand Energy Consumption/ storage tableaus versus improved Eco Energy Architecture; inputs/outputs from Systems Major Physical Benches and equipment development, and structure frame-Impact on the other side from Thermal Frame Benches.

Nodal-listed 3 categories of developments from Frame/ System

I 0,1 kWh/kg
II 10 kWh/kg
III >10 kWh/kg

Emerging ecolonomic use of water and air means that also Fluid Management Bench concepts will be contemplated, alongside the quantification in kg and respective absorption categories.

The nodes in the Architecture will be taken up by certain equipment simulators which bestow Eco-Design the relevant footprint connectivity [kWh, kg] without the equipment development by Systems ITD, or say „just“ material structure modules from airframes’ applications(low power or own energy harvesting sensor and many more complex multifunctional scenarios; passive mass in kg is at least manageable). This is a logics development built upon from the present ECO-EDS achievement, and is meant to make life simpler for Eco-Design Optimisation and Appraisal.

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\(^{33}\) Relative consumption rates may have to exacted, e.g. per 2min replenishment or as per process time unit etc.
Figure 13.14 - Eco-Design architecture partners
Eco Acceptance and Compliance Testing, direct ambient appraisal [T4]-purpose

A) This is an outlet to do also partial LCA analysis by test, with innovative Design of Experiment, without using a pure “LCA analysis”

B) For Activities for the quality and repeatability check-out evaluation; No flight physics, strength etc.

C) For Activities towards machine and human “contacting and perception”. Bio materials can have wide appeal but dusty or low quality part solutions, hazardous substance emissions are not a basis for good practice recommendations. Acceptance means the Baseline nuisance or expectations, sometimes an industry norm or psychological value, which is basely entrenched in the concept-part/equipment, before even discretion of ergonomics or comfort design can be concerned. Eco-Design flair has some pull in market enthusiasm. For instance oak wood (eco armatures) creates a certain positive ambience. So, Eco-Design tends therefore to the basic nuisance and acceptance, to research & test of deference of hazard-risks E.g. from harmful particulate matter to fire resistance, chemical exposure. Often, the measures integrated may have a large primary energy demand or use of strong global warming substances exposure through halogen substances, or just that manual handling is a problem. (Eco-Design is only a comfort and style partner; the real human centered research is in HUCCE and in the general cabin research “below” that. Together with Eco-Design though, real so-called enthusiasm value can be increased)

D) For Bigger ECOTech tests, that could be a large fire test with eco-extinguisher on one of its assessed modules. It could be an on-location styrene measurement, in parallel, the power take up, all along a new process for more rapid and clean RTM processes; complete closed loop cutting, through gates MRO practice exercises to physically derive the Bill of Processes etc.

On agreement with the stakeholders and through consultation of the regulations, it will be advised to collate a mapping of hazardous substances’ hot spots in a generic vehicle overview. This would accompany the EHP and ES outputs.
13.4.2 Eco-Design Analysis & Eco-Design Transversal Coordination

**Eco-Design Analysis** (EDAS) in figure 13.17 ensures an assessment of economic and environment results for the ITD/IADPs. The concept in the schematics is to allow an adaptable approach as much as possible. It uses both bottom-up micro and top-down macro approaches to the analyses of *Clean Sky 2* technologies and innovations interacting with Eco-Design themes. Thus implications for new products and markets will be assessed. This however is the start of a chain of manifold environmental, socio-economic impacts. These will arise through new employment opportunities requiring new skills. The impacts are also assessed from the internal *Clean Sky 2* performer and across the necessary process of innovation suppliers. [T6.1, T6.2]. The task contributions [T6.3, T6.4] give the “mechanics” of utilising the data. Beyond the classification by ITD/IADP it is by CS lessons learnt essential to differentiate by stakeholder and or technology pathway scenario the Bill of Process convention. The conformity and security must be ensured. Most companies, not even aware of EMS (environmental management systems) are usually far away from understanding the technical derivatives or very unwilling to disseminate data with consequences not understood. Therefore in most cases for even a simplified life cycle level, bi-lateral data collection teams at managed execution phases have to be set up.
The **Socio Economic Delivery** work package in the outgoing Eco-Design ITD was the only and possibly smallest WP in the whole running *Clean Sky*, this is currently being rectified, and in *Clean Sky* 2 a profound concept will be built in by consultation to the next Eco-Design analysis, delivering the quantitative and qualitative socio-economic derivative T6.2; It has its beginnings in the Eco-Design Statement [ES] work unit [T5] and ends with possible alterations to the DfE guidelines [T6.5]. In the first degree the CS2 ES is founded on quantitative Life Cycle Results [T6.0] expanded by Eco Architecture tableaus [T3] & regulation hotspot mapping, hybrid vehicle/module technology eco compliance maps. It will be ensured that any party can also participate to Eco-Design analysis without being an expert in Life Cycle Analysis or a tool developer in that field. There will also be experimental approaches [T4]; many handbooks have only outdated process backgrounds or no hard evidence sources at all available! It should be noted that without any ecolonomic harmonisation on the micro economic scale it is impossible to construct any valuable socio-economic delivery.

First a target challenge and development is given for the Eco-Design Transversal Activity impact in global warming potential (in equivalent CO₂ count) is given and secondly the socio-economic derivative risk. The relationship to general activity flow is also commented upon. One will then get back moreover to chapters on the LCA analysis in its basics, its advancement for the programme, including the non-analytical socio-economic part.

The schematic (Figure 13.18) overleaf gives a pathway in the development of *Eco-Design targets*; the relevant ITD/ IADP interaction GANTT bars are exemplified for interaction methodology only. The respective real WPs of the ITD/IADP, which are longer and more complex, should be looked up in the relevant chapters!

The best practice Eco-Design Statements “ES” are placed at regular and expected major review intervals. At the end of 2014 one will be able to validate the 7,5% **GWP** as useful gearing target to start consolidating the first designs with. Without excellent synergy with Next Generation Technology stream take-up, one could conceive missing a major global environmental gain, short fall of potential. That is the blue “super-effect” in picture from 2017 onwards. One has on the one side the insertion, verification of first eco hybrid frames/systems, then the next generation technology lead/wave from the ITD and final validation. Eco-Design in its part would strengthen successful Materials and Processes, take in the changes from the eco architectures, emerging primary energy trends and new resources, scheme specific supply chain exercises. Important outcomes are the big impact ensembles of technology process chains that are in line with the ITD-TRL, eco-compliance and user benefit expectations of the programme, innovators and integrators alike.

**The 15% GWP target reduction from Eco-Design** prospectus is not farfetched and is based on similar fairly gaged experience with other transport forms. The **socio-economic factor**, displayed as risk-opportunity gauge, is set arbitrarily at the beginning-marks of 25%, maximal reduction/ improvement decade potential, if the use-phase with strong fuel burn factor is complementarily scaled to 75%.
Figure 13.18 – Eco-Design Target Conception and Flow through into Major Activities

**Eco Target LEGEND** (Figure 13.18): **ES**: Eco statement, **SED** socio-economic derivative, **GWP**: global warming potential, **MPR** Materials Processes & Resources, empowered environmental engineering, **EHF/S**: Eco hybrid frame/system, **BITP**: Big Impact Technology Pathway, **MPB** Major Physical Bench, **VSCM** virtual system component module, **PM**: process module, **BSL**: base line

These high level targets, containing complex intrinsic effects will be also piloted by three significant simplified key performance impact (KPI) factors:

*The RE-cycle, RE-use quota (RRQ),*

*The equivalent ground pollution potential (GPP) and thirdly the*

*The advanced TA Eco Statement (ES) with the socio-economic statement (SES), owning an Eco Design socio-economic derivatives set.*
Due to high scrap rates during processing, end of life technologies and recycling are a key performance parameter/indicators to overview:

- reducing scrap rates & waste materials
- recovering materials
- recycling and reuse of materials

As can be seen even through standard process and materials screening, the impact in these straightforward terms is substantial, c.f. negative or CO2 eq. impact reducing mechanism in fig 13.19

This is brought together in the RE-cycle, RE-use quota (RRQ), drawing the total impact from the total Eco Design MPR inventory.

The ground pollution potential (GPP) is founded on the expanded Life cycle analysis portfolio.

The global ES, moreover socio-economic statement (SES) are not so straightforward but are targeted as newly constructed deliveries, their definition formed in the first year of the project. At least the thematics are explained for them after the multifaceted life cycle analysis is now shown.

The Life Cycle Analysis (LCA) based on the present Clean Sky experience should be tackled on three tiers, one for the major integrator called the simplified life cycle analysis (SLCA), another on the established but improving Clean Sky expert reference plane LCA+ and finally one for the care of supplier, SME considerations: supplier life cycle analysis (SupLCA). This latter group cannot be burdened by an architecture know-how capacity, especially for say an SME who has just a metal sheet folding workshop; this could count also for specific interest groups who just want to see how their process step(s) evolve. The supplier can have big process impacts that are often totally disregarded or unavailable in the analysis up to now, for instance in the production of intermediates, PAN fibres, AL-sheets etc.
A pictorial summary is given below (figure 13.20) for the collaboration principles:

Another experience from *Clean Sky* is that quite an effort in collecting useful bills of material (BOM) and bills of processes (BOP) is needed. This could possibly be attributed to the high performance and IPR issues of each participant in the process. In that case special data collection teams have to be set up, even bi-laterally to accelerate and safeguard the delivery.

The depiction (Figure 13.21) underneath gives up to date *minimal* LCA-impact differences if the processes and latest data bases are not meaningfully accounted for;
First applications of the specific aircraft component production by using generic models have shown that commonly applied material and standard process screenings drastically underestimate actual environmental impacts (see blue and red highlighted bars, namely for "Fuselage Material Screening" and "Fuselage Standard Process Screening"). Up to the case, the actual environmental impacts of the production of aircraft parts may be up to more than 14 times higher than the results of material screenings suggest. For components of other materials the errors of material screenings can be expected to be even more severe.
In Eco-Design generic models of the developed concept offer great flexibility for upgrades to company specific needs allowing them not only to environmentally optimise production but also to better market their products and can bring further steps about a new area of aviation.
Abbreviations of the LCA-factors (GWP, AP etc.) are given in an “LCA basics outline” below. Depending on component size and complexity (w/o full supplier network complexity!), the deviation factor already varies between at least 5 and 15.

In order to cope more discerningly on technical grounds, Eco-Design will not only encourage a special configurations management but also infuse an automated Life Cycle Inventory (LCI) seeking management. This is to cut the gap between 3 weeks, and partially 3 years delay or blank output because of complexity, benchmarked in the first Clean Sky loop!

It could also be suggested to get real field-, shelf- or integrated MRO-assimilated check-ups, perhaps capitalizing on the ITD-structural health monitoring (SHM) innovation output.
Clean Sky 2 will maintain a process-delivered part-to-vehicle LCA approach.

A view to a sophisticated Information Scenario is given at chapter end under “Expansion of 13.9 tables-part 3” It is also a vision-chart on the Design for Environment references and tool implementation in order to support advanced ITD/ IADP configuration objectives. Its aim is to show that it is facing a global innovation objective even on the basis of communication and information technology with multitudinous game changing frontiers

Life information technology (LIFT) is the only one possible asset needed to serve technicians and planners alike. Another avenue to be invented to avoid cul-de-sac engineering is titled Local And Nominative Conflict Extrapolation (LANCE) concept. A simple analogy could also be derived from reliability analysis for structural health. If you look at a body as nominative holder of care it is well known that very dispersed, often unknown locality problems (BVD, notches, surprise hair-cracks, post crack/ artificial expenditure) would have to be resolved, which is time consuming, with frustrating confusion- and knock-on effects.

For conventional systems and even commonality ruled components, aeronautics has outstanding requirements. If advanced new configurations, even just by shape-adaptation evolve, the whole supply, delivery innovation opportunities cannot materialize without constructive conflict engineering.

If this was a correct excellence view then one would have to ask how at all actors such as specialist SMEs could even economically participate to this; That led also to the incentive to firmly introduce an additional SupLCA level concept in CS2.

It is clear that pro-active simplifying and innovation liberating approaches are needed.

**Life Cycle Assessment (LCA) in its basics**

Life Cycle Assessment (LCA) within Eco-Design is one of the fundamental methodologies to assess the environmental performance of systems from material over component to product level. According to ILCD\(^{34}\) Life Cycle Assessment (LCA) is “a structured, comprehensive and internationally standardised method” which is defined in the ISO 14040\(^{35}\) and 14044\(^{36}\) standard. LCA “quantifies all relevant emissions and resources consumed

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34 ILCD: International documentation and exchange format for the documentation and publication of Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) datasets. European Commission - Joint Research Centre - Institute for Environment and Sustainability, 1995-2013; the database behind the ILCD data format is called ELCD database (as it is up to know dealing with European high quality datasets); an international database is planned.


and the related environmental and health impacts and resource depletion issues that are associated with any goods or services”.

To really account for all relevant emissions and resources the whole life cycle of the aircraft has to be considered. Therefore, all in- and outputs to the different life cycle stages have to be compiled in a so called Life Cycle Inventory. This approach is illustrated in Figure 13.23 - Life Cycle Assessment. Only with taking into account all in- and outputs of any involved process all environmental and health impacts can be quantified within a so called Life Cycle Impact Assessment where consumed resources and caused emissions are classified in Environmental Impact Categories.

Following Clean Sky achievements in LCA tools, databases, methodology and studies a further maintenance, improvement and extension of the output is suitable and necessary. Thereby consistency, continuity and high quality have to be ensured and the EU activities on ELCD and ILCD guidelines have to be supported, enhanced and improved to provide manageable standards for the aviation industry.

The ELCD ILCD database and format system acts as basic reference and structural standard for datasets to ensure consistency and comparability of LCA datasets used in the aviation industry and the ILCD handbook acts as methodology reference how to perform LCA studies.

State of the art impact categories are:
- Global Warming Potential (GWP)
- Acidification Potential (AP)
- Eutrophication Potential (EP)
- Photochemical Ozone Creation Potential (POCP)
- Primary Energy Demand, renewable and non-renewable (PED ren, PED non-ren)

The Primary Energy Demand – however – is not an impact category as it does not quantify an impact but energy consumption. Still it is often used to evaluate the energy efficiency of products.

37 In Clean Sky 2 the state of the art impact categories will be used as recommended by the International Life Cycle Reference Data System at the time of the analysis. http://eplca.jrc.ec.europa.eu/
To handle the complex systems of the aviation sector strong LCA software and database systems have to be used in combination with available up to date product information on materials and processes. The bill of materials (BOM) can show a hierarchical structure of the product with used materials, the amount of material used, processes how the material is used to build up components etc. Further information like buy to fly ratio, process energy consumption, used auxiliary materials, risk phrases, by-products, direct process emissions, supply chain information and information on data quality enhance the basis for LCA studies. In Clean Sky it has proven inevitable to lay out a separate but compliant bill of processes (BOP). This has the advantage of inducing management-capability of Intellectual property issues. Separation by pure material and mass is usually impossible.

<table>
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<tr>
<th>Level A</th>
<th>Level B</th>
<th>Level C</th>
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Figure 13.24 - Example bill of materials (BOM) in simplified mass terms, and simplified process hierarchy, simplified mass-only tabulation

**Life Cycle Analysis (LCA) in an expert approach: Going beyond Clean Sky - The vision for Clean Sky 2**

As various materials and production processes are used within the aviation sector it is mandatory to build up a detailed LCA database on material supply chains and single processing steps. The material database provide environmental information from “cradle to gate” which means from the raw material extraction over basic processing steps up to the delivery to aviation industry (e.g. for aluminium alloys, titanium, carbon fibres, various metal and plastic materials etc.). With better databases on production processes, the main steps in the production of aviation components could be greatly improved (e.g. shape forming, shape cutting, surface treatment, etc.). This means that the following topics have to be addressed in Clean Sky 2:

- LCA database: maintain, improve and extend Clean Sky LCA Database, ensure consistency, continuity and high quality, follow ILCD methodology and structure
- LCA tool: maintain, improve and extend Clean Sky LCA Tools, ensure consistency, continuity and high quality as well as compatibility to ILCD methodology and structure on the level of the Life cycle inventories LCI from partial processes up to full vehicle level and consistent process scenarios.
- LCA methodology: further harmonize LCA methodology in LCA for studies in the aviation industry, provide ILCD conform guidelines, ensure consistency, continuity and high quality
• LCA studies: perform LCA case studies from material over component to whole aircraft and socio-economic surround\(^{38}\) level, show performance and improvement of materials, processes, component production and whole systems

The special focus and challenge of the aviation industry is the use of advanced materials, innovative and integrative technology process flows (next generation of smart LCA tool for the aviation industry). The high ideal is to assess the full product life cycle to avoid any apparent “improvements” by simply shifting environmental impacts from one stage of the life cycle to another; otherwise not missing the costs or remediation effort if negative shifting is still unavoidable.

Within *Clean Sky 2* new impact categories can be included, if the scientific basis is given, these impacts are:

- Toxicity Potentials, HTPS\(^{39}\)
- Water footprint\(^{40} 41 42\)
- Land use consideration & biodiversity aspects\(^{43} 44\)

Eco-Design is particularly concerned with, acidification, eutrophication any contamination or health risk sensitivities.

If this is hard to scale in importance, various Commission publications can be referenced, underpinning tremendous annual economic costs through non-attendance to the subject matter of indirect ground pollution.

The Eco-Design content can be carried out in an efficient way. The existing experience, capability and knowledge in the field of LCA and the material/technology and part development in the aviation sector will lead to cohesive and coherent outcomes, especially for *Clean Sky* and the European Commission. This will result in reduced time, consequently decreasing costs as well as increasing capacity building for serving as an important role and frontrunner within environmental analysis in the aviation sector on an international level.

By integrating the consistent approach, the Eco-Design development of materials, processes and resources will allow a comparison of current and future technologies and aircrafts from

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\(^{38}\) In *Clean Sky* a so-called “fleet” level has been attempted, probably similar to stability of SHM data exercises. This was a mistake; there is no LCA monitoring job in flight operations. You only get an aggregation by vehicle No. by type. Value is rather in the comprehensive ES and compliance levels from component to vehicle level. Moreover the embedment of effects in the Life cycle themes particularly for the manufacturing base new production, control of lifecycle resources consumption and impact in the socio-economic surround.

\(^{39}\) ILCD handbook: Recommendations for Life Cycle Impact Assessment in the European context; Chapter 3.3 on Human Toxicity.


a Life Cycle point of view by taking into account the same system boundaries. Furthermore by implementing Eco-Design in the aviation sector, an impulse for the reduction of the consumption of finite resources, such as oil, will be supported leading to sustainable solutions (e.g. by establishing sound product category rules for a sustainable assessment in commercial aviation in line with EC requirements).

**Merging Economic and Ecological factors**

In T6.0 of fig.13.17 various costing approaches are indicated which can be very complex such as LCC or simpler as DMC. A lighter economics appraisal through various advanced factors can be dressed into the LCA today by the following parameters:

- Net Present Value (NPV\(^{45}\))
- Work Effort Unit (WEU\(^{46}\))
- Shelf Life Account (SLA) inside and outside production.
- Relevant (time unit and) history scale (RHS) at LCI part

![Image](image.png)

Fig. 13.25 Outside production gates shelf life and logistics load case

*Clean Sky* has introduced concepts similar to MARCI (Mitigate, Assure, Redeploy and Cumulative Impacting) tracking in its management approach.

In a similar manner—but on a more technical level—Eco-Design in *Clean Sky* 2 can respond to give good feed-back, also to account risk & potential related issues to the JU or general management reporting, transversally and inside IADP/ITD and/or within a technological scoping exercise.

An example of this stems from an actual LCA analysis, giving a supplier requested feed-back on 4 technological process variants, here reduced to just net price value (NPV) considerations with weak *quality function deployment*, to keep it „simple“ in the following plot (Figure 13.26).

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\(^{45}\) The Net Present Value (NPV) is summing up the discounted value of cashflows within each period/year of the study period. It thereby allows comparing the economic aspects of different scenarios. It allows to decide whether a project should be conducted or not; respectively to choose the most favourable option from an economic point of view.

\(^{46}\) Takes respect to international labour organisation neutral work force units for employment growth and also calibration effort to repair ecological and economic damage.
The environmental impact is normalized from the LCA-footprints to get a comparison with one of the approaches used as norm basis, here: “S1”

We can set the scenario in the sense that:

- Top left sector I: Worse performance (environmentally & economically worse)
- Sector II & IV: Depending on user preferences, whereby here increasing environmental impact has been equated to utility or potential for environmental benefit (the more to the right the better)
- Sector III: Better performance (at least economically better)

So in this case study the owner of the technology could just opt for process S4, being more affordable than pathway or process S3. The large environmental opportunity of S2 may not be taken up because it is more expensive; but this might look different if neighbouring supply trading is considered.

Alternative economic factors can be chosen. Eco-Design is a continual opening to deliberate other straight forward trade-off assessments, e.g. direct manufacturing cost, cost versus weight sensitivity optimization for more scenario flexibility not just savings, best practice life cycle cost (LCC), ownership cost interaction, financing differences etc.. This means an economic assessment of reference and newly developed parts, components and innovations, derivation of the environmental weighting and normalization factors based on Clean Sky targets that should be fulfilled to conduct and integrated economic and ecologic assessment (workshops to train partners in the work with integrated assessment).

Choosing the right LCA impact data, form of acquisition (by test, analysis etc), the right ensemble and right dependence or independence for that is a huge challenge in its own right and cannot be upheld by just one approach alone. A short project view without meaningful real product life scenario data and so on is hardly manageable. It is a long term process that will always contain qualitative and enthusiasm factors beyond the quantitative scoping. Eco-Design will be made open for this. Yet, the mentioned quality function deployment, done by groups of the EDAS or VEES activity with the ITD/ IADP engineering can be monitored to safe guard expectations not running away from the ITD/ IADP TRL delivery.
In all circumstances, a participatory review should complement any such analysis to ensure a balanced stakeholder view. The best approach is self-identification of responsibilities, avoidance of any conflicting questions / outputs (e.g. IPR), pursuing a well understood, feasible and accepted roadmap of excellence.

**Eco-Design participatory socio economic analysis**, abridged from present Clean Sky deliverables:

The aim is to get a joint balanced stakeholder view on the status quo, through questionnaires, briefings, reviews, external scientific views etc. An example generation of results in the appropriate Eco-Design angle is given below. More detail at this point of time cannot be given without called in project partners, scientific and general societal forums. It will of course follow an agreed strategy (resource and material efficiency in aeronautical value chains (production, operation and end of life) through efficient service processes, integration of social belongings into Eco-Design requirements and design for environment chart).

![Figure 13.27 - Participatory (non-analytical) socio-economic discourse charts](image)

In case of general level cul-de-sac discussion loops Eco-Design can get advice from the new scientific committees on content for specific societal survey needs. The whole socio-economic appraisal will observe EFQM standards. No individual Eco-Design participant will be exposed in the discourse.

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47 European Foundation Quality Management EFQM, “Taking Responsibility for a Sustainable Future: Excellent organizations embed with their culture an ethical mind-set, clear values and the highest standards for organizational behaviour, all of which enable them to strive for economic, social and ecological sustainability.”
Reference of other Research Programmes and Projects

All activities with regard to Eco-Design in Clean Sky 2 build on findings of previous research programmes & projects and deal with not yet addressed aspects to unfold its full potential for sustainable aviation.

Important groundwork for establishing a basic foundation for sustainable aviation has been done in the research programmes and projects:
- PAMELA (Process for Advanced Management for End of Life Aircraft)
- NICETRIP (Novel Innovative Competitive Effective Tilt Rotor Integrated Project)
- CORINE (Design optimised to reduce environmental impacts)
- CLEAN SKY JTI (Joint Technology Initiative)

Within PAMELA Airbus and Suez-Sita. EADS CCR and Sogeram Services as well as the Hautes Pyrenees Prefecture elaborated a management approach for the End of Life of aircrafts – one of the three major phases within Life Cycle Assessment based Eco-Design.

A full Life Cycle Assessment Study has been carried out for one specific tilt-rotor airplane within the NICETRIP project, a collaboration of 31 partners from industry, research organisations, academia and consultancy coordinated by Agusta Westland. For this pioneer project in the field of Life Cycle Assessment of complete aircrafts no aerospace specific, and in particular no aerospace component specific, baseline data was available. Even though results hence were only representative for one particular aircraft and of limited precision in general, they represent an important milestone for Eco-Design of aircrafts and paved the way for further research in this area.

Within the CORINE project Life Cycle Assessment of five particular helicopter parts was carried out employing case specific baseline data. For the analysis an eco-design tool specifically developed for the project was used, following a simplified analysis approach. With CORINE the ten partners, Eurocopter, Bonnans.sa, Carbone Forge, Expiris, REXIAA, Solution F, EcoMundo, CARMA, LCE and the Universite du Var ISITV TVT delivered further valuable insights regarding the specific environmental impacts of particular helicopter parts.

The CLEAN SKY Initiative then raised Life Cycle Assessment in the aerospace sector on a completely new level. With the joint force of the 12 ITD Leaders, 65 Associates and 473 partners for the first time Life Cycle Assessment of complete aircrafts was carried out employing aerospace component specific baseline data, collected within a large-scale data collection among ITD Leaders, associates and partners. The complexity of such component specific whole aircraft LCA, which has to describe great number of different components in an aircraft, was tackled by a specifically developed up-scaling approach and Eco-Design software tools. This boosted both the practicality of basic aircraft Life Cycle Assessment as well as its precision. Yet it discovered many limitations necessary to be addressed in order to evolve the basic CLEAN SKY I Eco-Design into a transversal activity throughout the industry and so unfolding its full potential. This will be one of the key tasks for Eco-Design in Clean Sky 2.
13.5  Eco Design Transversal Activity Coordination

At the moment each ITD/ IADP has at least a communication WP on level 0 and/or General Management mainline delivery level. In the large Airframe ITD, the main “WP Eco-Design 3.5” and WP0.5 as General management partition, with the interfacing gain through activities on Material, Processes and Resources(MPR) activities between the high level Airframe configurations HPE and HVE.

Further linking into the start-up configuration of Work Packages is given in the WP reference matrix in section 13.9, and the coinciding figures 13.8, 13.9. This is a starting point for the global work flow anchoring. Thoughts on governance and the proceedings are given in the separate chap. 13.7

The management in task [T0] has three pillars. Each one is also cross-referenced with the other TA-[Tasks]

T0.1 is responsible for transversal synthesis and general management reporting as in [Tech] transversal innovation progress towards excellence, thus follows up the work of Sub-teams to support the collaborative EDAS and VEES initiatives explained below; [Coord.] general management reporting duties to the ITD/ IADP/ TE interfaces and reporting duty to the JU-programme office- [WP0.51 Airframe], [TA-CSJU Programme office] respectively. T0.1 serves also the preparation of the coordination committee and eco design assembly, supervises and reports the performance of T0.2 and T0.3 delivery.

T0.2 is the TA Clean Sky general value execution activity on Materials, Processes and Resources, motivating workshops, deepening the LCA-issues and informing on new regulation developments- [WP0.52 Airframe] and other mainline delivery work links such as defined by ITD/ IADP-Joint Technology Programme chapters, headed “eco design”

T0.3 Dissemination Input/ Output Communication, support to the ITD/ IADP, JU-programme office in this respect, check-in and check-out support to participant contributions; serving the population analysis of eco compliance improvement, global key performance Indicators on aeronautics recycling and reuse, key resource footprints and architecture hotspots (REACH sensitive, water depletion, energy class potentials etc.) complimentarily to the TRL assessment of the ITD/ IADP).

The leader will be held responsible for ensuring and alerting regularly the dissemination levels of the eco design beneficiaries and will delegate a manager on the level of the TA and to the level of CSJU to specifically chase all necessary initiatives in reference to the programme office general management manual and yearly communication plans from the Governing board level. This could mean that external workshops, for instance during important exhibitions are solicited by the JU and supported by the TA. Higher level communication can be mutually agreed through the coordination committee as a reoccurring agenda item. The dissemination policy shall be concurrent with the GB decisions solicited through the JU programme office.
The Participant Level

The specific CS grant agreement texts derogated from the HORIZON are not in practical text for instance in regard to the “new openness”. Still, a few items can be really pre-organised:

Every deliverable template will include the Horizon coding for dissemination and if relevant include a short publishable executive summary part. Along with the socio-economic check-in-check-out questionnaire for each participant receiving an eco design grant agreement there will be an Individual Company Dissemination File (ICDF) which is filed into the eco design Dissemination and Communication Plan (DCP). The DCP concept is half yearly updated in its general communication text. The separate ICDF can be updated anytime by the relevant contact, which is chased otherwise by the T0.3 management.

ICDF content does not repeat the inherent contract deliverables or exploitation elements. Moreover the ICDFs annexed to the DCP, highlight:

- Specific person responsible for communication in the company
- Level - General/ Clean Sky, -Eco Design/ CSJU yellow pages partition
- Specific technology personalities, e.g. expert working on anodising
- News/Press
- Media (Flyers, videos, posters etc.)
- Exhibitions (supporting CS at Le Bourget etc.)
- Workshops (MPR, LCA)/ Events (Design for Environment)
- Conference proceedings/papers
- Academia/ Education Thrust (PhD, Labview, University views, Data Collection/ Eco Design Data Hand Handbook discourse on the discipline design for environment as a future professional vocation etc.)

First steps in synchronising the eco design TA programme

In 2014, the set-up of the transversal activity will be managed together with the understanding and definition of requirements from ITD/IADPs in line with technology stream contribution to be assessed from a life cycle’s perspective. Initial activities will concern definition of all the 3 activity delivery levels and ways of interaction with ITD/IADPs/TE for the implementation contracts.

Based on experience you need people not just pert charts, hands-on to drive management solutions and real synchronisation of activities.

Sub-teams to support the collaborative EDAS and VEES issues will be set up that continuously monitor, optimise links and responses and submit recommendations to the Eco Design TA committee. They will also draw intelligence from the Eco Design ITD best technology athlete assessments 2008-2014, and scale out the new quality function deployment versus the following dimensions:

a) Input ITD/ IADP, TRL and contributing factors to this (not owned by TA)
b) EDAS factors, responsibility owned by TA
c) VEES factors, shared responsibility
The Work units’ definition needs to be assessed through a dedicated deliverables. This is not to be underestimated as can be seen by examining just one IADP tableau in the next figure.

Figure 13.28 Regional Aircraft IADP WP - Eco Design Task correspondence table background, showing the GRA/EDA reference (building on Clean Sky success), the IADP-Airframe ITD draw-up.
13.6 Preliminary thoughts on the Eco-Design Governance and Proceedings

The Eco-Design global transverse activity is a huge opportunity to link and integrate the ITD/IADPs on strong concrete common topics at the grass roots of Clean Sky. It could help prevent silo management and narrow vertical technology perspective risks.

The commissary Eco-Design Leader, bearing the founding risk is the Fraunhofer Gesellschaft under the formal auspices of the CSJU.

The Eco-Design proposal is set behind a continual consultation process because it is very multi-dimensional, not only on technical terms and cannot be finalised through this document alone; As a guidance, the present CSJU has provided a proposal, c.f. consultation presentation (Frankfurt, April 2013).

A non-comprehensive elaboration of this:

- The Transversal Activity (TA) Eco-Design is neither an isolated statutory Eco-Design ITD nor a gross WP in a particular ITD, not even the ITD Airframe with highest inheritance volume from CS1. This TA is an integrative and bonding activity, promoting excellence from the base throughout all ITDs and IADPs without exception, creating synergies and complementarities for the Eco-Design tasks allocated through WP annual/multiannual implementation work plans within the ITDs/IADPs.

- Most of its growth potential will come from cfp partners; an opening for core partners will come only after the first ITD/IADP wave of openings, c.f. paragraph “partnership”.

- It has a Transverse Activity (TA) coordination committee formed by representatives of each involved IADP/ITD chaired by the TA leader, including its PO + others if relevant would honour participants contributing substantial additional activity assets.
  - to input for CFPs definition between TA and IADP/ITDs to guide Eco Statement preparation, allocation of implemented activities;
  - to give a global map of activities;
  - to elaborate the Eco-Design agreed road maps for Eco-Design in CS2 work based on the IADP/ITD plans and work scope, and make to appropriate periodical updates;
  - to synthesis the IADPS/ITDs Eco-Design actions into global Eco-Design achievements at CS2 level;
  - to prepare support to the Design for Environment internal/external stakeholder consultations.

- Eco-Design will organize annual reviews (wishfully synchronized to TE reviews) with participation of the respective management representatives of ITD/IADPs, to monitor the Eco-Design status and provide guidelines for the best coordinated continuation of the effort. Major review makes sense at selected major cross-cutting points e.g. end of 2017, at 2019 or 2020 and closure.

- Eco Design will provide a more global participation awareness. This means that in conjunction to the annual reviews so-called assemblies or forums of all participating beneficiaries (cfp or member alike) will take place organised by the TA leader. The PO and TA leader can ask for several presentations directly by the concerned cfp partner equally from the members.

- Preparation of MPR and LCA regular focused work-shops and major Clean Sky technical forums on those themes to encourage excellence and enrichment on common need matters, dissemination, materials data bases ref. fig. 13.11 and strategies arising from new regulation developments.

- Creating a wide scale bonding of the programme and special work plan overview contribution. The supporting PO reports the state of play through the chief PO to the GB which includes three key

2014 Clean Sky 2 Joint Technical Programme (V4) – Proprietary Information subject to Confidentiality Agreements
performance indices on the global TA level and the visual build-up of the Eco hybrid platform (EHP), compound components and vehicle contributions with profound life cycle benefit gains.

13.7 Partnership

The Eco Hybrid Platform is not only a compound of vehicle parts it encompasses value building socio-economic parts, e.g. factory, RE-cycle etc. therefore specific cluster activities may called in for complimentary research. The activities allocated in the ITD/ IADP to Eco Design tasks T1 to T6 as well as coordination under task T0 are accumulated to an Eco Design grant agreement (GA). The beneficiary will be offered an implementation agreement and ITD/ IADP consortium agreement, covering further specific issues of management and compliance needs on the Work Package and ITD/ IADP the tasks of the participant’s research is connected to.

TA Eco Design will specify call for partners topics and also call for core partner activities based on need, of course allocated to the final ITD/ IADP reference. It is not impossible that such a partner could be bridging for instance an activity say between an ITD and IADP. For such considerations consensus on how to proceed will be achieved through the coordination committee with the support of coordinating leaders. In such a way the partners could also be considered as instrumental to propel also activities from the ITD to the IADP planes.

Eco-Design will, allocated budget allowing, consider some openings for core partners; they would strongly contribute to the EHP delivery

A: a core partnership: defined through the Airframe ITD leader specification (“advanced configurations”) which could also manage forward looking issues on adaptive life cycle inventory management specified in return by the TA. The challenge is epitomized by the vision in figure “Expansion of 13.9 tables-part 3: Tentative Concept Reference, DfE vision, tools serving configuration excellence”

B: a core partnership(s): major cabin or wing materials/ components innovation realisations, ideally at the interface between ITD/ IADP, specification defined concurrently IADP-TA. Alternatively, by several intermediate larger cfp tasks, say in support of the human centred cabin, LifeCraft etc. agendas can also be scoped.

C: a core partnership(s): systems i) embedded/ packaged technology equipment and new COTS concepts answering to long term SupLCA initiatives, systems ii) armatures, equipment, treatment and connection for power/ energy, controls, major reliability (such as Landing Gear) answering to long term SupLCA initiatives.

Eco-Design mainly foresees call for partners (CFP) to boost lead-in avenues with new technologies for successful pathways of high TRL CS basis at measurement year 2014, helping the next technology waves 2017-19.

This can entail also many small to medium focussed projects that can be answered by dedicated academia, small medium enterprises and special labs. Next CIP waves also depend on the progress of LCA validation closing technology gaps, Eco Statement and Design for Environment progress. It is important to get high network coverage of the so called Eco Life & REcycle themes in the Clean Sky technology population. Eco-Design will eagerly manage the small players and new entrants based on the positive experience from Clean Sky Eco-Design ITD, the newcomers bringing in special skills and experience that are not typical in aeronautics.
The Eco Hybrid Platform is not only a compound of vehicle parts it encompasses value building socio-economic parts, e.g. factory, RE-cycle etc. therefore specific cluster activities may called in for complimentary research.

These would target supply chain cooperation on the level of close regional actors in order to improve material flow (eco) optimality, in parallel to say to several aeronautical activities. As an example a portfolio of parts that are to be delivered to systems’ equipments. In return the supply chain scoping and SupLCA could be concretely constructed, interdependent life cycle inventories and logistics loads properly evaluated.

**ITD Engine will be supported specifically** by even three first programme-half cfp calls, addressing tools, new specification and advanced materials & processes. Core Partner involvement would be decided for the advent of the second call for core partners.

Since it is important grasp Eco Design results at the grass roots, every beneficiary will be confronted by a simple questionnaire for each relevant activity level regarding eco design Life cycle improvement objectives. This will also be compared by this beneficiary and reported at an intermediate and final stage at least. It will include an extract on the socio-economic check-in expectation, check-out improvement, incl. relevant dissemination results and exploitation potentials. This will probably necessitate a rigorous consultation process.
## 13.8 Preliminary draft of reference WP areas of the ITD/IADPs allocation of Eco-Design Activities

(Pending Eco Statement (ES) references and review in 2014).

<table>
<thead>
<tr>
<th><strong>Activities in IADP/ITD</strong></th>
<th><strong>Eco-Design Work Units</strong></th>
<th><strong>LPA</strong></th>
<th><strong>Fast R/C</strong></th>
<th><strong>R-IADP</strong></th>
<th><strong>AIRFRAME</strong></th>
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<tbody>
<tr>
<td><strong>[T0] Eco-T0.1/3</strong></td>
<td>Eco-[UP] Global(macro-economics eco-derivative) Socio Economic Impact closure TE WP3.4 applicable, WP2.8 interface; external T0.3 TA-CSJU Communication, T0.1 TA-CSJU Admin./Coord.-Interface; technical forum &amp; workshop-MPR</td>
<td>WP0.2</td>
<td>WP0.3, WP 2.1.5</td>
<td>(WP0.3 NA. Since ITD interface lead, statutory body communicati on....)</td>
<td>WP A 0.4 and B 0.5 Cross Interaction (fig.9.8): management of interfaces with Eco-Design transversal Activity, at interface between HPE-HVE(0.1/.2/.3/4.5) as Eco-T0.1/3</td>
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<tr>
<td><strong>Eco-T0.2</strong></td>
<td>WP 0.2 Eco-Design</td>
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<td>WP A5.1, A 5.2 Materials Processes Resources as Eco-T0.2</td>
<td>NA. lower or base level WPs connected to tasks below, managed by <strong>WP11.7.2</strong></td>
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<tr>
<td><strong>[T1]</strong></td>
<td>Lead-In activities (incl. Upgrade/ spec. Prep. [T6.4], LCI anyway)</td>
<td>in ITD level</td>
<td>in ITD level</td>
<td>in ITD level</td>
<td>WP A 5.1, WP A 5.2, A3.4 (i.e. theme [A]:Scope&amp;Identifica tion v. [B]:MPR)</td>
<td>LCI definition two selected super-material scenarios</td>
<td>New processes, defining an Inventory into Life Cycle Inventory(LCI) including scope for new processes, e.g. <strong>WP11.7.2</strong></td>
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### Key implementation of Eco-Design focused developments within the IADPs/ITDs

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<tr>
<td><strong>Eco-Design Work Units</strong></td>
<td><strong>Realisation/Dedicated Life Value Technologies</strong></td>
<td>Next generation integrated fuselage concept, structure, cargo and overall system integration outputs; manufacturing &amp; assembly Eco themes [B], [C] and [ADS], , WP 2.1.2, WP 2.2.6, WP 2.3.1, WP 2.3.3, WP 1.5.2</td>
<td>NGenCTR WP 1.4 - LifeCraft WP 2.2 through streams III, IV; work cooperation through airframe HPE5.1, HVE4.4</td>
<td>WP 2.1.1: Development of the Liquid Resin Infusion (LRI) process for green fabrication for &quot;economical&quot; production of Regional AC wing stiffened panels by low (Out of Autoclave - OoA) energy curing</td>
<td>W A-3.4 : development of eco-technologies for airframe</td>
<td>ECOTech on special metal, exotic material composites for Smart, Affordable Life Cycle Engineered stage parts ensemble or module rig level; composite blade LCI optimisation</td>
<td>Strengthening MPR, next generation surfaces, tribology treatments <strong>WP100.2</strong></td>
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<td>Airframe str. 8.5.12 WP2</td>
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<td>WP A-3.1: MPR</td>
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<td>WP A-3.3 (Demo); B-1.2; B-3.4; B 3.3, B-4.3; B-4.4: technologies for green manufacturing and &quot;economical&quot; production</td>
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<td>[T3] Eco Architecture</td>
<td>WP2, WP3 outputs, WP 2.3.1, WP 2.3.3</td>
<td>Common data base enrichment standards WP 2.2</td>
<td>WP2.1.1 outputs (A3.4) &lt; &gt; IADP, System handover; out of scope for Engine under budget scenario I (which is alternatively loaded e.g. in LAIADP WP1)</td>
<td>LCE rel. weighting function output, consumables &amp; scrap load, Primary energy demand example case investigation</td>
<td>Major Physical Benches, Equip Env. Classif -outputs; REACH on new alternative materials/processes map WP11.7.2 and WP110.2</td>
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<td>[T4] Acceptance &amp; Compliance</td>
<td>WP1, WP2</td>
<td>Possible expansion of WP2.1.1 EoL test versus RE-use challenge of Thermoset</td>
<td>WP A5.1, WP A-5.2 &amp; WP B-4.4: eco-compliance for cabin layout</td>
<td>after 2017 ES understanding/ Need definition</td>
<td>Methodologies (Req.) for supply chain to reduce import Eco Risk or hazard.../ proof of ruggedness of lead free part..</td>
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<td>[T5] Eco-Design Statement, Design for Environment (DfE), Input to Eco-Design Statement ES</td>
<td>WP0.2 &gt; Route Book, Socio Economic Derivative (micro economic &amp; user benefit/commendation part), participatory discourse, WP 2.2.6, WP 1.5.2 (under revision)</td>
<td>WP1.3 Route Book, Socio Economic Derivative (micro economic &amp; user benefit/commendation part), participatory discourse</td>
<td>WP4.2 &gt; Route Book, Socio Economic Derivative (micro economic &amp; user benefit/commendation part), participatory discourse</td>
<td>W A-3.4, WP A 5.2</td>
<td>rel. ROI, NPV improvement, after 2017 ES understanding/Need definition</td>
<td>expanding on EDA ES input versus new service benefit, first aeronautics systems (DfE) on future classifications, low ecological footprint optimisation scenarios discourse WP11.7.2</td>
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Big Impact Technology Pathway (Eco BITP = generic route book basis)
### Key implementation of Eco-Design focused developments within the IADPs/ITDs

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<th>ENGINE</th>
<th>SYSTEM</th>
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</thead>
<tbody>
<tr>
<td>Eco-Design Analysis (Incl. Ecolonomic Harmonization)</td>
<td>WP0.2, Contr. WP1-3, SLCA (gen); advanced, matured and systemised LCA on Cabin&amp;Cargo components probing LCA+ excellence-focus case, WP 2.2.6</td>
<td>SLCA building on GRC6 and LCA+ on selected components, post 2017</td>
<td>WP 4.2: Collection data and technology assessment of the developed technologies; inputs for LCA evaluations</td>
<td>W A-3.4: LCA database, Life Cycle aggregation/analysis for representative airframe part</td>
<td>Specific SLCA or support T4 case approach if available To+2yrs; At To Integrated Manuf. Test case LCE derivative output into LCA framework depending on [T1]: results</td>
<td>Specific SLCA or support T4 case approach; focus &quot;Integrated maintenance&quot;, &quot;Human Factor/Work effort&quot; Improvement, Definition of micro-economic ecological harmonisation targets in the ITD system socio-economic derivative</td>
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</tr>
<tr>
<td>[T6]</td>
<td>SLCA capacity regional a/c depends on budget scenario development</td>
<td>WP A-3.3: fuselage demonstrators for eco impact assessment pilot case</td>
<td>SLCA capacity engine depends on budget scenario development</td>
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13.9 Preliminary Draft of Technology Story Board Examples

In the main Eco-Design core text and in Airframe there are many elaborate themes such as out of autoclave (OoA), friction stir welding processes and so on. The idea here is to:

- Draw attention to the Systems and Engine tableaus and some important remarks, as well as some ECOtech project concepts where common actions with airframe could give a helping synergy.
- bring in the synergy prospectus but also show where differences to more pure ITD/IADP technology streams with or without TRL or eco compliance could be picked. A certain differentiation is achieved by the „V“ or „TS“ coding explained below. The amount of technology tasks is only a small sample of around 30 examples and is only to allude to principles for, synergy of common activity, coverage of the Eco-Design Life themes and NOT to fix these as a particular selection. In Eco-Design ITD around 230 on EDA and 136 on EDS domain were originally at the start-up.
- exemplifying this arbitrary selection for activities also within the capacity of small to medium enterprise, sepecial lab and academic research capacity level. Large Manufacturer interaction etc. is already mentioned in the ITD/IADP sections.
- suggest some task areas with advanced approaches to what has been done up to now in the running CS Eco-Design ITD but also examples building on CS success stories.
- This swift technology review is without the issues of the LCA analysis, broadly reviewed in the chapter core text. It is only alluded to by the “V” under „MPR strengthening“ explained below. The responsible participant will also in the project describe the initial desired socio-economic benefit, individually evaluated with the user perspective and outgoing specific result, the Eco-Design organisation will utilise all of the outputs to support the conjecture on Life cycle coverage by technology; on another dimension the implementation scenarios accumulate to form the eco hybrid platform coverage and compound vehicle/system and architecture coverage.
- Cooperation for best vehicle ecological, economic synergy (VEES) through common activities, sometimes “ALL“ are involved.

Systems and Engine

The biggest volume on an aircraft is taken up by Airframe, still the value intensity of Engine and Systems is high. Eco-Design will encourage stronger impacting leverage from the Engine and Systems portfolio. At present, these partitions are still under consultation since a strong part is supposed to come also from call for proposals. A possible taste of activities in the Materials, Processes and Resources is shown in tableaus I & II below. It should also be pointed out that there are often great differences in the employed materials not just commonalities with Airframe, furthermore the MRO impacts often have to be managed differently. Drilling into a super alloy is quite different to a cabin material plastic. In the case of Engine often the term life cycle engineering (LCE) crops up and should n’t be confused with life cycle analysis (LCA), it is as engineering activity stored under T2 tasks for engine. LCE also pursues a product strategy, design, applied technologies, monitoring and assistance.
**Engine ITD tableau of Eco-Design Life technology realisations**

- **Major Physical Bench outputs, developments for improved environmental footprint GWP, Energy, Water consumption;**
- **Eco-Design for life methodologies for economic life appraisal;**
- **Alternative development for scarce high performance material implementation;**
- **Life cycle cost and Eco-Design benefit analysis, Life Information Technology;**
- **Clean technology application (surfaces, lead free, etc.; REACH/ RoHS substance substitution);**
- **Equipment lead free/ REACH compliant ruggedness;**
- **Landing Gear Treatments;**
- **Environmental Control System parts;**
- **Wheel Concepts- Attrition, Life value;**
- **Eco Compliant Production and new equipment services, integrated maintenance etc.**

Because of the intricacy in systems and obviously different engine weighting in LCE and MRO, strong use phase[UP] demonstrator angle, it is obvious that the right Eco-Design WP-level is rather much more embedded in the intrinsic equipment, component impacts. Thus advice from the scientific committees in collaboration with the TA, engine and systems leaders to construct best potential WP-Eco tasks at end of the first year will be followed. Engine and systems will first want to trial various new technologies with the support of Eco-Design management e.g. very first cfp technology scoping and assessment, definition of LCI and their technology reference scenarios.
Explanation of technology story board orientation

The first elements reference the Eco-Design Life and Recycle Themes, these characterise the Eco-Design activity performed in tasks, ref. in fig. 13.10

The descriptor Initials [A, B, C, etc.] are referenced again in the following table:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>REUP</th>
<th>EoL</th>
<th>ADS</th>
<th>ASA</th>
<th>Relevance/cooperation potential - ITD/IADP</th>
<th>MPR strengthening</th>
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[A] next generation life scoping, factor on the life phases with new life information technology to improve and enable an Eco-Design Life according to the developed concept of Design for Environment (DfE)

[B] Materials Processes and Resources (MPR); is main red tape bond and multiplication factor around the Life and Recycle phases

[C] Manufacture/production these are to different (access) life phases; present impacts have still to be discretized. Eco-Design CS2 recognizes though that through adaptive manufacturing, maintenance in manufacture, assisted in-line assembly production etc. the separation of these access phases must be reserved for the impacts and industrialisation evaluation conclusions on the next generation technologies.

[D] Service to component and system, this is far more comprising than MRO, it includes material flow, logistics, management methodologies, storage, inside outside gate processes and SERVICES for the supply chain.

The initial CS avenue of „just“ long life as „only“ strategy has been expanded so that a withdrawal phase and extraction phase is minimised in a final Design for Environment Strategy. A stronger view to Re-use avenues is also to be contemplated.

[REUP] Re-Use. Eco-Design encourages a more closed loop material flow, for the need to keep the diminishing resources (super alloys etc.) inside the aeronautics product envelope.

[EoL] End of Life, in the case of Re-Use failure i.e. characteristics of product are beyond rejuvenation, high downcycling, the hands on management and technology for EoL has still to be considered because right now higher a/c volumes of hundreds of a/c with engines etc. have to be technologically treated and not just dumped e.g. per landfill, with poor mechanical sorting.

[ADS] Integration/field, factory Assembly-Disassembly-Separation

[ASA] Alternative Sectoral Applications. If the REUP cannot be exploited then this avenue is technologically exploited i.e. high performance aeronautics derivatives are used as enabling technology not otherwise available. Built environment, medicine, feeding stock, other transport capacities/ synergies e.g. deeply drawn parts, advanced cleaning, powder/melt base for special construction, dual use liquid/water recycling etc.

[UP] use phase, this is just a passive but important complementarity entry as life phase in relationship to the Technology Evaluator. The UP is therefore omitted in the story board examples below.
NOTES
- Eco-Design is not working on the direct technological reductions or monitoring of fuel burn, it is more concerned with the bottom-up global flow to reduce ground pollution and to improve in that respect the ecological and economic impact with the involved processes.

Relevance/cooperation potential.- ITD/IADP
Single, combination of ITD or even ALL participation

**MPR strengthening** is reduced to base materialistic reference just for the ease of a general common denominator!

- (M) Metals
- (P) FRP, other plastics
- (SM) special reinforced material e.g. metal matrix, multifunctional
- (BM) Bio-materials
- (C) Ceramics, electropolar
- (S) Supply Chain, supplies
- (OTHER) Consumables and important OTHER hydraulic fluid, lubrication, functional and passive seals gaskets, etc.
- (V) LCA expansion, DfE- Life cycle Engineered (LCE) profitability
- (TS) Technology Stream lead, feed back interest for Eco Design

1. **Turbine Recycling**

**Scope:** Recycling of aviation turbines

**Target:** Development of an automated process chain for disassembly of turbines, including the recovery and recycling of materials and parts

**Status Quo:** The recycling of turbine is currently being considered only at the edge of the product life cycle. In most cases, turbines are largely destroyed to come to the recyclable parts as quickly as possible. All non-recyclable parts are disposed as scrap for consideration. This leads to a mixing of materials such as titanium, nickel based alloys and conventional steel. It is estimated that up to 1000 turbines might need to be recycled each year.

**Innovation:** Substitution of the destructive manual processes by a systematic disassembly. Decomposition of the turbine in reusable parts and recyclable raw materials. Integration of the gained parts into the maintenance cycle. Treating, such as melting, of the recovered raw materials and returning of the materials direct into the turbine manufacturing process.

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2. **Finishing of ceramics and CMC**

**Scope:** Finishing technologies for the machining of ceramics and CMC parts

**Target:** Development of processes for praxis and high quality orientated finishing of complex components
**Status Quo:** Compared to currently predominantly used metallic materials the application of ceramic and CMC components offers high potential regarding the reduction of weight and increase of efficiency in aviation. Due to excellent mechanical properties, ceramics and CMC even can be used in highly dynamic stressed parts, e.g. milling tools.

**Innovation:** One of the big challenges of ceramics and CMC is the development of stable and cost-efficient machining processes:

- Analysis and reduction of the influence of finishing processes on mechanical material properties
- Development of solutions for the machining of complex and difficult to reach geometries

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3. **CFK machining robots**

**Scope:** CFK processing

**Target:** Development of an automated process chain for the CFK processing using industrial robots

**Status Quo:** The size of these fibre-reinforced structural components continues to increase. For the cutting processes of the parts milling and waterjet cutting applications are used. The future development of the size and requirements of the parts have a direct effect on the applicable technologies and machines.

**Innovation:** Introduction of an integrated finishing process using industrial robots. Adaptable working area by use of linear axes to compensate the increasing workpiece size. Simultaneously, reducing the investment costs compared to a machine tool with a similar work space.

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4. **Edge Machining Robot**

**Scope:** Automation of the manual edge machining process

**Target:** Development of an automated process chain for edge machining, based on the flexibility of industrial robots

**Status Quo:** Components of aircraft engines must have workpiece edges with defined roundings or fillets. The necessary contouring is either being carried out on CNC milling machines right after the machining in one setting or as a labour intensive manual post-process

**Innovation:** Substitution of the manual processes by use of industrial robots. To relieve the machine tools in order to improve the economy. In this context an increase of the process reliability and reproducibility will be possible.

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5. **Milling of Superalloys with ceramics – SuMiC**

**Scope:** Establish a process chain for the high speed milling of Superalloys  
**Target:** Tool development and process strategies  
**Status Quo:** For the improvement of the turbine efficiency factor the turbine infeed temperature has to be increased. For this reason new materials are developed that are more temperature stable but that are harder to be processed. For a full exploitation and processing of those new materials a new processing technology is needed, that allows the production while taking into account the factors of time, costs and quality.  
**Innovation:** New cutting tools, geometries that adapted to cutting- and processed-material and processing strategies are developed. The goal hereby is the reliable and economic machining of nickel-based-material as well of other difficult-to-machine materials in industrial framework.

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6. **Flexible process chain for additive manufacturing**

**Status Quo:** Currently a continuous additive manufacturing process with the required quality, stability and assurance during the process is not given. Aviation manufacturers need robust processes and integrateable process chains which can be certified. New AM technologies like selective laser melting offer improved quality but still need more intelligent process monitoring for the quality documentation. Because of resource scarcity, shortened product life cycles in addition with tight innovation cycles, manufacturers have to use new technologies with the aim to reduce production time & logistic costs of turbine parts by using AM technologies with integrated quality management.  
**Innovation:** Development of process chain with AM technologies for cost- and time-efficient manufacturing of turbine parts:  
- Flexible process chain for additive manufacturing with per- and post processing  
- Integrates quality Management and Condition Monitoring for a continuous online monitoring  
- Integration with a supplier & technological benchmark  
The combination of technologies and their application follow the approach to realize an economic manufacturing.

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7. **High efficient airframe cleaning**

**Scope:** Optimization of cleaning processes of entire airframe  
**Target:** Development of a blast-cleaning technology and device for high efficient cleaning of in- and external surfaces  
**Status Quo:** Currently the cleaning of interior equipment as well as external airframe surfaces is a time consuming manual process.
Different cleaning processes require a huge variety of tools. Possible surface damage due to the removal of residues discourages an efficient process.

**Innovation:** The development of a cost- and time-efficient cleaning process:
- Surface specific adaption of process parameters offer a uniform cleaning technology
- Possible (partial) automation
- Avoiding of damages due to task specific parameter settings
- Avoiding of emissions (removed residues, sound pressure level, etc.)

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8. **On-Wing Maintenance Repair and Overhaul**

**Scope:** On-Wing engine MRO

**Target:** On-Wing cleaning, repair and endoscopy methods

**Status Quo:** Currently the cleaning, repair and endoscopy control of engines requires time and cost consuming processes. Those often require the disassembly of the whole engine.

**Innovation:** Development of On-Wing “cleaning, repair and endoscopy methods” for cost- and time-efficient maintenance and overhaul procedures of engines:
- Miniaturization of maintenance methods for On-Wing applications
- automated final using of the tools

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9. **Fuel Cells used as a ground power unit with reduced environmental impact**

**Scope:** Development of fuel cell system for use as ground power units (GPU), for the silent and low-emission power supply to aircrafts while grounded

**Target:** Demonstrator of a GPU using HT-PEMFC technology

**Status Quo:** Current ground power units (GPU) for the supply of electrical energy to airplanes are based on diesel generators or the combustion of other fossil fuels. This technology has low energy efficiency and causes emission of air pollutants, greenhouse gases as well as noise to the environment.

**Innovation & Objectives:**
In the project a HT-PEMFC based GPU shall be investigated. Beside low noise and emission levels typical for all fuel cells the HT-PEMFC offers further advantages
- Operation on hydrogen or reformate possible
- Higher resilience against airfield contaminants
- High quality heat for possible future applications, e.g. heat and chilled water supply
10. **Inline production of plastic cables for signal wiring**

**Scope:** Assessment of manufacturing and production of polymer-based aircraft wiring

**Target:** Assessment of potential for improvement of energy balance through plastic wiring: novel materials, material processing technologies, contacting technology, robotic manufacturing technology

**Status Quo:** Wiring in aircraft is largely based on copper and aluminum wires. The wires are assembled to harnesses before they are brought into the aircraft and contacted. The process is labor and resource intensive.

**Innovation & Objectives:** The innovation is the use of plastic cables for aircraft wiring. Conductivity is obtained by additives. The wires are extruded from plastic granulate directly during the wiring process and attached to components or extruded in free space. This project focusses on application scenarios and their potential to improve the overall energy balance quantified by experiments. It includes the development of suitable tools and parameter sets for the processing of materials and automation systems for the wiring and contacting process.

- Assessment of application potential of plastic cables in aircraft wiring
- Material development and research of tools and parameters for material processing
- System components (robot system, extrusion tool)
- Configuration of robot system for automated wiring based on process model
- Feasibility studies for application of plastic cabling in aircraft production
- Experimental determination of primary production energy demands and energy efficiency of plastic wiring in comparison to traditional wiring

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2015 Clean Sky 2 Joint Technical Programme (V5) – Proprietary Information subject to Confidentiality Agreements
11. **Eco-Efficient Robust Electric Power Conversion**

**Scope:** Establish and exemplify a model based optimisation strategy for the development of extremely light and robust power electronic devices in aircrafts

**Target:** Reduction of weight and size by 50% for power electronic devices with an assured robustness

![3-phase inverter for actuation of helicopter rotor blade](image)

**Status Quo:** For the energy, materials and cost efficient integration of power electronic modules in an aircraft environment, these modules need to be developed to achieve the minimum possible size and weight, while an optimum robustness and lifetime needs to be achieved. This process of optimization is time consuming and cost intensive. Therefore often not all optimization potentials are used.

**Innovation & Objectives:**

The challenge is solved by development of a coupled and model based optimization scheme, which addresses the main issues of lifetime, thermal cooling, weight and materials efficiency.

Integration of innovative highly reliable packaging technologies.

The results will be made available on an internet based design platform

**Technology Target & Content of Work:**

- Identification and ranking of key failure and efficiency criteria.
- Set-up of technology demonstrators for new upcoming technologies (embedded power, advanced thermal interfaces), life time evaluation and set-up of lifetime models
- Development of advanced cooling architectures
- Integration and application of an optimization scheme for thermal, materials and lifetime aspects for the size reduction of a functional demonstrator
- Set-up of demonstrator and proof of concept
- Publication of design guidelines and spread sheets usable for effective predesign

**Deliverables**

- Lifetime models and cooling architectures, 01/2015
- Tested technology demonstrators, 01/2016
- optimized, 01/2017
- set-up and proof of concept, 12/2017

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12. **Anodizing goes Clean Sky**

**Scope:** Energy consumption in production and material properties  
**Target:** Reduction of the energy consumption for anodizing of lightweight construction materials (aircraft aluminum alloys, magnesium, titanium) and improvement of the material properties  
**Status Quo:** Anodizing of lightweight materials for corrosion resistance.  
The temperature of the electrolyte must be kept at 0°C during the whole process despite of the thermal input.  
**Objectives:**  
- Reduction of the energy consumption of 20% (cooling power) through increasing the temperature of the electrolyte.  
- Improvement of the material properties like fatigue behavior, mechanical strength and reducing the material inventory.  
Especially Anodizing of aluminum alloys, magnesium and titanium for aircraft  
  - Reduction of energy consumption  
  - Improvement of material and layer properties  
  - Effect is realized by development and optimization of the process parameters current and voltage  
  - Development of new electrolytes  
  - Development on a special three-dimensional test object  
  - Characterization with typical testing methods out of practice

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13. **Robot-farming: Portable robotic assistant for joining processes**

**Scope:** Assessment of novel system for manufacturing and production of structural assemblies  
**Target:** Development of laboratory demonstration including lightweight tools with low force reactions, system safety concept including process related hazards, in fuselage mounting technologies for robot, software for robot farming  
**Status Quo:** In-fuselage joining operations (drilling, riveting) of structural parts are carried out manually. Highly qualified workers are used for repetitive tasks on safety critical joints. Recent developments allow the use of lightweight robots in close cooperation with humans, but system safety aspects demand attention.  
**Innovation & Objectives:** The objectives are the implementation and evaluation of a lightweight robot system able to perform joining operations inside the fuselage, including safety aspects. Special emphasis is on the operation of several robot systems by one operator (robot farming).  
Within the project the required components (tools, interaction software) are developed and integrated into a demonstration platform.

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14. **Energy balance for production process of Al – MMC – Nanocarbons**

**Status Quo:** New Materials like Nanocarbon based metal-matrix composites offering a wide range of material enhancement. Actual Research has not yet addressed energy consumption for the processes involved.

**Objectives:** To offer a set of data-values which can be used by the industry to make a Life-cycle analysis in the production steps of aluminium based carbon-composite materials.

- Energy related analysis of the production steps of powder based aluminium composites with values derived of experiments. Incorporating the mixing step of raw materials and forming processes.
- To generate characteristic values for physical property related energy usage for comparison with standard materials e.g. E-Modulus per Energy unit
- Processes to be analysed: Milling, sintering, extrusion
- Energy related analysis of production steps for MMCs through experimental data

Information for SMEs on possibilities of energy, waste and cost reduction by offering published data

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15. **Smart Processes for Integrated Airplane Manufacturing**

**Scope:** Manufacturing and cutting technologies for structural components

**Target:** cost reduction in manufacturing processes like cutting, milling and drilling of airplane structural parts; based on intelligent, interacting and automated systems

**Status Quo:** Today single processes with no interaction, based on optimization of single steps on empirical basis, causing expensive process setup with low adaption to changes and developments in machines, tools and processes.

**Innovation & Objectives:** At first today’s single manufacturing subsystems (cutting, clamping, exhaustion, quality measurement) are integrated in single models with intelligence due to self adaption and operation. Following the single intelligent subsystems are combined to the total manufacturing system, to enable overall process validation and value based optimization for cost reduction. Within the project the required models and subsystems are developed and integrated into a demonstration platform based on a robot drilling and riveting system.

- Modeling and development of subsystems with intelligent components and software for self adaption and optimization (cutting tools, clamping systems, quality control, exhaustion)
- Merging of subsystems to setup a manufacturing system with communication, control and optimization interfaces
- Demonstration system with self adaptive manufacturing process for drilling and riveting
- Cutting technologies, exhaustion systems, quality assessment, clamping systems and simulation
- Manufacturing modeling, automation and optimization
16. **Large Positioning System for Inspection and Painting**

**Scope:** Large-Scale Automation Equipment for Surface Processes

**Target:** Improvement of surface quality of large structure parts (wings, fuselage) with respect to reduction of deviations in weight of the paint

**Status Quo:** Inspection, Cleaning, and Painting of Aircrafts is today completely manual process. Thus, it is difficult to control the amount of paint applied to the surface of an aircraft.

**Innovation & Objectives:** The aim of this project is to analyze the effectiveness of automated inspection, cleaning, and painting in order to reduce the weight of the aircraft and to make a quality control in cost efficient way.

The use of large-scale cable robots promises to perform automatic motion along the contour of huge components of the aircraft such as fuselage and wings. Within the project the effectiveness of this approach shall be evaluation based on the form of the components, the expected quality of the processes, and the reduction of weight.

**Technology Target & Content of Work:**
- Reachability studies for large components of the aircraft through planning, 3D-simulation, and tests on scaled prototypes
- Feasibility studies for the inspection, clearing, and painting processes w.r.t. the accuracy, velocity, and processes forces to be applied
17. **Ultrasonic Testing under limited accessibility**

**Scope:** Laser and conventional ultrasonic testing device (LUT/UT) for NDT of limited accessible engine parts  
**Target:** In-situ wall thickness measurement and material characterization of alloys, prospectively CMCs, by **lance-like ultrasonic probes.**  
**Status Quo:**  
Routine checks cause high cost due to dis- and re-assembly. Standard NDT testing based on disassemble single components causes unwanted ground time. More efficient engines are today possible but strongly retarded by the tradeoff between long testing intervals and mandatory safety margins.  
**Innovation & Objectives:**  
Shifting ultrasonic testing towards fully assembled engines  
Use of existing access points for visual inspection for adapted ultrasonic probes  
Combination of conventional endoscopic techniques with tip-contacting ultrasonic micro probes and laser-ultrasonic probes  
Investigation of portability standardized ultrasonic testing  
Wall thickness measurement and material characterization by endoscopic laser-ultrasonic probe.  
- Definition of application suited ultrasonic and laser-related parameters and thresholds  
- Extension of existing laser-ultrasonic test site towards fiber coupled beam guides  
- Modeling and alignment laser-generated ultrasonic wavefield  
- Assembly of beam guides and ultrasonic micro-probe to supporting hollow shaft  
- Definition of ultrasonic calibration curves at different materials  
- Adapt parameters to data analysis for operators software  
- Measurements at metallic single parts and CMCs  
- Incorporate specific needs of on-site measurements

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18. **Hybrid Phased Array Characterization of Carbon Fiber Reinforced Plastics**

**Scope:** A combined ultrasonic-eddy current phased-array technique for characterization of CFRP structures  
**Target:** Enhance resolution in CFRP characterization over the complete life cycle at no additional cost.

**Status Quo vs. Innovation & Objectives:**  
**Status Quo:** CFRP structural inspection on ground by ultrasonics only. Environmental degradation effects are covered by safety factors, which increase weight.
Innovation & Objectives: Provide a system for handheld inspection on ground with enhanced microscopic resolution to quantify potential degradation effects in CFRP structures, based on materials characterization parameters. This will allow lighter weight design since CFRP structures can now be inspected even during its operational life in the sense of damage tolerant design. A flexible transducer array will allow to adapt to a variety of different structural shapes. Signals recorded will be processed in accordance to a sampling phased array data processing procedure. Results obtained will be stored in a materials characterization reference database.

Deliverables
- Testing concept including hardware, software & sensors: Q3/2015
- Electronics and sensor prototypes: Q2/2018
- Classification algorithms based on test measurements: Q1/2020
- Combined ultrasonic/eddy current phased array sensor: Q4/2021

Involved Competences:
- Multi-channel phased array platform PCUS Pro Array, ultrasonic and eddy current NDT systems, sensors development, simulation center, sampling phased array

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19. Production Integrated Testing for Aero Engine Turbine Components

Scope: Reliable production of lightweight components for energy efficient aero engines

Target: Establish reliable multi-method NDT for production control and quality assurance of aero engines

Status Quo vs. Innovation & Objectives:

Status Quo: Lightweight components allow for lighter weight turbines leading to enhanced energy efficiency of vehicles (green operation). Today quality of production is normally tested post manufacturing and/or finishing. Not all defects can be detected in those stages. For some of the newer and very efficient production technologies such as selective laser melting (SLM) generative production, there is no sufficient quality control available at the moment.

Innovation & Objectives: Small defects are hard to be identified when the part is ready. The innovation is to use production integrated testing with a multi-method synergetic approach to identify material weaknesses already during manufacturing.

Technology Target & Content of Work:
- Identify material types, components and appropriate novel production technologies where Production Integrated Testing is essential (e.g. SLM produced materials)
- Identify for each material and manufacturing type most promising method or combination of methods among ultrasound, eddy current, optical methods, x-ray and others

PINT example in SLM manufacturing of free form turbine components: SLM with back side integrated ultrasound phased array detection of lack of last layer adhesion and eddy current array detection (parallel to the wiper) for lack of solidification
- Adapt the selected methods to the materials, geometry etc.
- Modeling of the sensor defect interaction and signal generation
- Simulate and optimize sensor geometries
- Design, optimization and realization of sensor-prototypes
- Sensor handling and manipulator development
- Induce manufacturing flaws and test the hard- and software developed
- Development of algorithms for improved data analysis
- Verification of the procedure under real onsite manufacturing conditions

**Deliverables**
- Identified materials, production processes and testing methods for PINT, first demonstrations: Q3/2015
- Adapted methods and sensors for improved PINT operation: Q2/2018
- Integrated (multi transducer) application including handling: Q1/2020
- Verification in several application scenarios: Q3/2022

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20. **SpeckleFinder – detection of optical fingerprints on aerospace parts**

**Scope:** To recognize markers or marked material structures, tracking of parts during manufacturing, protection against forgery and mix-up

**Target:** Speckle photometry for tracking and tracing, implementation of a speckle photometer for inline trace, chip-microscope as mobile speckle-tracker

![Speckle dynamics](image)

**Status Quo:**
Manufacturing and inspection processes in aviation have to be safe. Different marking and tracking methods for components exist. Most of them require extensive devices or long time measurements. Speckle photometry as a method of materials characterization offers a fast, contactless and robust technique to identify speckle patterns and to track them through several processes.

**Innovation & Objectives:**
- Concept of inline tracking via invisible speckle-fingerprints in a scale of micrometers to some 10 micrometers.
- Adaption of speckle-algorithms on tracking.
- Inline implementation of speckle photometer in processes.
- Speckle tracker in size of a mobile phone for mobile tracking – a very new microscopic method without optic lenses.

**Technology Target & Content of Work:**
- Identification of suitable aerospace products and processes → concept
- Adaption of speckle algorithms on tracking
- Realization of a prototype of speckle photometer for tracking fingerprints
- Implementation of speckle photometer in processes
- Realization of chip microscope as speckle tracker
- Laboratory and inline measurements for testing of devices

**Deliverables incl. TRL and Due Date:**
- Concept of speckle photometry for tracking as lead in new technology scoping.
- Speckle algorithms for tracking
- Prototype of speckle photometer
- Chip microscope as speckle tracker
- Prototype of speckle tracker

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**Scope:** To establish a complete wireless SHM System for CFRP structures based on acoustic guided waves

**Target:** Further enhance lightweight design by damage tolerance and optimize maintenance by automation. Example: a large scale module-packaged solution for Manpower & Service-affordable Regional Aircraft applications freely exacted at available access points and major str. control points.

**Status Quo vs. Innovation & Objectives:**

**Status Quo:** SHM systems mainly based on guided waves are proven as a concept by ground testing, but as a network on large structures SHM still becomes a challenge.

**Innovation & Objectives:**

A wireless SHM system is the next technological step enabling novel design strategies and condition based maintenance for safe and reliable aircraft transportation. The SHM system will be realized by QI standard wireless power supply and communication interface to transmit diagnostic results to a preferably handheld device without time-consuming inspection and disassembling.

**Technology Target & Content of Work:**

- Test of low power sensor network for guided waves based SHM, specification of communication and energy parameters
- Optimization of these parameters considering the QI standard and design of power supply and communication interface
- System tests on ground for practical test scenarios
- Calibration / validation on large test panels to identify design uncertainties
- Sensitivity analysis for different operational conditions, POD of the whole system

**Deliverables**

- Concept design and functional hardware and software model for SHM sensor network
- Ground test data from sensor network for verification
22. Hybrid Air-borne Ultrasound Inspection

**Scope:** Establish a dry, non-contact ultrasound testing technique with high lateral resolution for automated testing of structural components

**Target:** SMART NDT for MRO

**Status Quo:** Modern structural components have to satisfy a number of requirements which can only be ensured by sufficient integrity of the parts and their correct repair within the maintenance concepts. One important testing issue are in-service defects and the reliable and smart non-destructive inspection of secondary bondings.

Therefore, advanced NDT techniques are required which overcome the drawbacks of conventional NDT methods (e.g. expensive safety precautions, contamination as a result of testing and limitations for complex shaped parts).

A new NDT technique using air-borne ultrasound in combination with EMAT methods within an innovative hybrid sensor system (HAI) is a very promising alternative.

**Innovation & Objectives:** Contactless inspection in through transmission technique by dual robot-techniques for complex shapes. Testing with one-sided access employing Lamb waves (guided waves)

Possibility for pulse-echo-testing on the basis of the new technique (HAI)

- Simulation of hybrid ultrasound transducers
- Development of tailor made transducers for examination of complex geometries and small radii
- Development of new hybrid transducer concepts to improve signal-to-noise ratio and for realization of one sided pulse-echo testing
- Implementation of advanced signal processing for pulse-echo testing and examinations using Lamb waves
- Implementation of dual robot usage for through transmission and one sided testing methods
- Automated visualization and interpretation
- Development of air coupled ultrasonic systems for high speed data acquisition and inspection using robotized components
- Prototypes of new transducer designs
- High speed data acquisition systems by dual robot usage. Automated combination of through transmission technique and one-sided inspection of complex structural components
- Visualization and automated interpretation of data
- Validation of the HAI system with approved test specimens in order to reach

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23. **End of life bio recycling (EOL-Biorec)**

**Scope:** Development of efficient and durable bio composites / fiber composites that can be decomposed by special microbes / enzymes under special conditions

**Target:** industrial integration of improved materials and recycling processes

**Status Quo:** Great effort in recycling of airplane components, especially of composite materials necessary.

**Innovation & Objectives:** In order to improve recycling of EOL aircraft parts biotechnologically improved microbes / enzymes shall be used for decomposition. Newly developed bio composites / fiber composites shall be enzymatically / catabolically dissolved so that valuable parts of the composites can be reused (fibres) and the dissolved matter can be used for e.g. energy production. Concept and development of new materials shall be conducted by reverse engineering.

![Image](http://4.bp.blogspot.com/zQCJyaX7G8/Tn86pMqsBLI/AAAAAAAAI48/_4jJNHjeluw/s640/Creative+Melting+Chair+by+Philipp+Aduatz-01.jpg)

![Image](http://30.media.tumblr.com/tumblr_m3dggkJ2DB1rp1ih1o1_500.jpg)

**Technology Target & Content of Work**

- Concept for an improved recycling process by use of microbes / enzymes (“biomelting”) in order to liberate valuable components for reuse
- Development of new bio composites / fiber composites for aircraft use which are “biosoluble” by special microbes under special conditions - reverse engineering
- Realization of a prototype / demonstrator in mock-up

**Deliverables**

- Concept design and functionality test for an improved biotechnology based recycling process (Q3/2016)
- New bio composites / fiber composites in concordance with recycling concept (Q3/2018)
- Testing of materials for a/c use (Q1/2020)
- Prototype / demonstrator application (Q3/2021)

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1* [http://4.bp.blogspot.com/zQCJyaX7G8/Tn86pMqsBLI/AAAAAAAAI48/_4jJNHjeluw/s640/Creative+Melting+Chair+by+Philipp+Aduatz-01.jpg](http://4.bp.blogspot.com/zQCJyaX7G8/Tn86pMqsBLI/AAAAAAAAI48/_4jJNHjeluw/s640/Creative+Melting+Chair+by+Philipp+Aduatz-01.jpg)

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24. **Self curing surface by desquamation**

Scope: Development of a self curing surface by desquamation of the surface layer (sacrificial structure)

Target: improvement of service life and maintenance cycles of surfaces structures.

Status Quo: The outer surface layer is of crucial importance for safe operation.

Innovation & Objectives: A multi-layered surface material that sheds one surface layer (sacrificial structure) at a time, if necessary and induced by special conditions (e.g. electric impulses), may improve service life and maintenance cycle of parts. The peeled off layer should be biodegradable. An opposite built-in approach to present additive processes.

Technology Target & Content of Work

- Development of a multi-layered polymer structure that sheds its surface layer after a certain impulse (special light irradiation, warmth, electric, etc.)
- Uppermost surface layer shall be biodegradable after desquamation, but not before
- Technical application of the multilayered polymer structure

Deliverables

- Concept design and overview of potential solutions for the multi-layered polymer structure (Q3/2015)
- Test of deliberate desquamation of uppermost sacrificial structure (Q4/2016)
- Biodegrading process of peeled off surface layer (Q1/2019)
- Prototype application (Q3/2020)

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25. **Booster energy by anaerobic digestion core to improve bio-thermal architecture**

Scope: Development of a system to use anaerobic digestion of organic waste for booster energy production on an airplane, accessing-locking system warmth/moisture, alternative energy approaches, more flexible sanitary/galley architecture for 3D passenger model. Comprehensive system architecture that involves not only use of lavatory waste and bio waste from the galley, but also condensation of the cabin insulation and liquid accumulation from the fuel reser voir; warmth production also usable for cold fuel temperature revival.

Target: reduction of energy, waste balance of an airplane, widen design capacities for eco- and human centered design concepts

Status Quo: Apart from fuel and energy supply, maintenance and fixed conventional methods- architecture is a locking part on the running costs definition for airplanes. All-electric or more mature conventional architectures vision only.
Technologies: fermentation, microbioms, pathogenic kill temperature frontier at around 60°C, capilar-diaphragm-, special fleece- networks e.g. at interior insulation boundary, low/moderate temperature heat transfer, small and large aircraft fuel system concepts, local agents functionality as described through repair bacteria below.

Innovation & Objectives: Booster energy derived from biogas conversion supplied by anaerobic digestion of organic waste on an airplane, hold warmth potential for cold soak starts etc. could reduce fuel demand of an airplane and thus also minimize the CO2 footprint of commercial flights; also special concepts to lock excess moisture/thaw and control fouling.

Technology Target & Content of Work (as just one avenue branch)

- Development of a system for production of booster energy by biogas from anaerobic digestion of organic waste on an airplane
- Practical design for realization of anaerobic digestion and biogas use on an airplane.
- Technical application of anaerobic digestion of organic waste at an airplane

Deliverables

- Concept design and overview of potential possibilities for organic waste collection and anaerobic digestion on an airplane (Q3/2015)
- Technical, practical and hygienic prerequisites for realization of organic waste collection and biogas production on an airplane (Q4/2016)
- Anaerobic digestion and biogas utilization according to the developed concept on lab scale (Q1/2019)
- Full scale test (Q3/2020)

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26. Repair Bacteria (ReBac)

Scope: Find suitable bacteria that perform structural repair work at damaged surfaces and parts, life and health environment enhancing.

Target: direct application in demonstrator after proof of concept in submodules/ risk pocket environments, application on aqueous colloidal and contact corrosion cell scenarios
**Status Quo:** Little damages in hard to reach places or structures may cause substantial repairs costs.

Innovation & Objectives: Certain bacteria are beneficial to mankind in many ways. Some may prevent and even repair corrosion. Some are antagonists of unwanted or infectious germs. And some are characterizing a health promoting environment. Investigation of bacteria strains and mixtures as microbial repair “team” for damaged parts which are hardly accessible.

Technology Target & Content of Work:
- Development of a microbial technique for the employment of beneficial bacteria for structural repairs
- Evaluation of beneficial species of bacteria which fulfill the desired requirements and can be composed together
- Development of a technique for use of repair bacteria at hardly accessible spots
- Bacteria for curing or preventing beginning corrosion, exterminate other unwanted microorganisms

Deliverables incl. TRL and Due Date:
- List of potential beneficial species of bacteria which fulfill the desired requirements and can be composed together (Q2/2015)
- Concept of application (Q3/2016)
- Test of application at lab scale (Q1/2017)
- Test of application at realistic environmental conditions (Q3/2021)

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27. **Building on Clean Sky Success – Tartaseal**

“Chromate free and energy efficient sealing of TSA anodic films for corrosion protection”

- **Project partner:**
  CEST (Austrian Competence Centre of Electrochemical Surface Technology), Vienna,
  Leader direction and support through Airbus

- **Background:**
  Tartaric Sulphuric Acid (TSA) Anodising according AIPS / AIP 02-01-003:
  The TSA process is applied for painted (app. 95%) and unpainted parts (app. 5%) for Airbus aircrafts. To meet the corrosion protection requirement, sealing is one of the options. Today, this sealing process step is still carried out in chromate based solutions (dichromate hot water sealing and/or Cr VI containing conversion coating), which needs to be replaced.

Conclusions **Clean Sky @ Y2013**
- Standard hot water sealing does not fulfill the requirements for production parts (e.g. SST resistance ≥ 336 h).
• Therefore, today CrVI based products and process steps are used for sealing of TSA anodic films in the case of unpainted parts.

• Sealing processes and products screened in this project show that REACh compliant alternatives are available, which fulfill the requirement with respect to SST.

Further work needs to be performed before use of the Cr-free sealing alternatives for TSA anodising to reach TRL6 and prepare Qualification.

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28. Building on Clean Sky Success for alternative sector development of geopolymers, feedback for aviation materials & reuse of recycled carbon fibres in construction areas

Scope: Design and development of various geopolymers for aviation industry & reuse of carbon fibres in construction areas

Target: Evaluation of industrial applications

Status Quo:
Geopolymers are a class of inorganic polymers, usually formed by the reaction between an alkali and an alumino-silicate source. They can be produced at room temperature and have a low CO₂ impact. Depending on the formulation, source material and manufacturing, they possess different properties:

- High Compressive Strength
- High Tensile Strength
- Resistant to Acid Corrosion
- Heat and Fire Resistant

Geopolymers are already used e.g. as exhaust pipes in formular-1 racing cars

Innovation & Objectives:
The chemistry behind the formation of geopolymers is not well understood, there’s a need to develop suitable analytical methods.

Geopolymers will be foamed, rein-forced by (carbon) fibres or adapted in a way that they can be used in a wide range of aviation areas.

Technology Target & Content of Work:

- Modifying and testing the properties of geopolymers by foaming, fibre addition, etc.
- Understanding the formation of nano-structured geopolymers
- Identifying suitable analytical tools for characterization of geopolymers
- Validation of potential application areas in aviation (runways, heat and fire resistant materials for e.g. cabins, etc.)
- Reuse of products from carbon fibres (chips, fibres, carbon dust, etc.), recycled by pulsed power fragmentation, pyrolysis, etc. in construction areas

Deliverables

- Identifying and development of suitable analytical tools for geopolymers Q3/2015
- Assessment of key factors for geopolymers production Q2/2016
- Evaluation and demonstration of application areas for geopolymers and recycled products from carbon fibres Q4/2017
29. **Building on Clean Sky Success, Bio-based flame retardants and raw materials for PU foams**

**Scope:** Reduction of CO₂ footprint of PU seating cushions by using raw materials based on renewable resources.

**Target:** Investigation and Manufacturing of PU seating cushions to enable the industrial application. Investigation of organic flame retardants for flexible PU foams.

*PU cushions with expandable graphite after fire testing*

**Status Quo:**

Today the degree of substitution for standard PU foam raw materials max. 50 % without a loss in comfort. Further improvements require critical research activities to enable the industrial application. Currently there are no bio-based flame retardants for flexible PU foams industrial established.

**Innovation & Objectives:**

- Development and characterization of green PU formulations and bio-based fire protection additives

**Technology Target & Content of Work:**

- Evaluation and partially modification of bio-based raw materials
- Adjustment of PU formulations for application
- Production of testing samples
- Characterization of mechanical properties
- Fire testing according JAR 25.853, typical Eco T4 task

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2015 Clean Sky 2 Joint  Technical Programme (V5) – Proprietary Information subject to Confidentiality Agreements
14 Technology Evaluator

14.1 Introduction

A Technology and Impact Evaluation infrastructure remains an essential element within the Clean Sky PPP, and the TE will be reinforced and continued in order to ensure monitoring, assessment, communication, orientation of the JU and IADPs/ITDs/TAs. Impact Assessments currently focused on noise and emissions will be expanded and evaluated against the Programme’s delivered value. Where applicable they will include additional impacts, such as the mobility/connectivity benefits or increased productivity of Clean Sky 2 concepts.

The progress of each demonstration platform (ITDs and IADPs) will be monitored against well-defined environmental (Noise, CO2, NOx) and socio-economic (Mobility/Connectivity, Employment, GDP impact; no competitiveness) benefits and targets. In the case of full vehicle-level demonstrations as in the IADPs, the core aircraft performance characteristics will be reported by the IADP to the TE under the responsibility of the leading company.

The IADPs will provide verification and validation of the aircraft designs proposed. In the case of the Clean Sky 2 ITDs, the TE will enable an aircraft-level synthesis of results in such a way (via ‘concept aircraft’) that the ITD results can be shown at aircraft level and evaluated within the Airport and Air Transport System alongside IADP results. The TE / Impact Evaluator function will reside within the JU. Impact Assessments of Clean Sky 2 outputs will be the responsibility of the TE / Impact Evaluator and will focus on aggregate impacts.

Based on lessons learnt in Clean Sky, the following principles will be followed:

- The Progress Monitoring of Clean Sky 2 achievements versus defined environmental and societal objectives will be established via an efficient and effective interfacing between TE and the ITD IADPs through dedicated work packages (TE WP2 and ITD IADP dedicated WPs).
- The evaluation at Mission Level will be done by integrating ITD outputs into TE concept aircraft / rotorcraft models (including innovative long term aircraft configurations); and in the case of IADPs receiving IADP concept aircraft / rotorcraft models.
- The concept aircraft / rotorcraft models will be input for impact assessments at Airport and ATS Levels.

The composition and rules of procedure of the governing body of the Technology Evaluator shall be proposed by the Executive Director and adopted by the Governing Board at a later stage.
14.2 Going beyond Clean Sky

With respect to Clean Sky, the TE in Clean Sky 2 will primarily widen its scope through the following aspects:

- Establishing and enhancing an independent Mission Level modelling capability;
- Integrating IADP concept aircraft and TE concept aircraft in the assessments;
- Defining and modelling generic airports at Airport Level;
- Assessing socio-economic impacts (not including competitiveness) at ATS Level;
- Enhancing the TE-Information System’s functionalities;
- Monitor Progress of Clean Sky 2 achievements versus defined environmental and societal objectives.

14.3 TE Interaction with IADPs and ITDs

The interaction between on the one hand TE and on the other hand IADPs and ITDs is shown in Figure 14.1. The TE will perform three activities: Monitor technical Progress of Clean Sky 2 achievements through TE assessments versus defined environmental and societal objectives, integrating ITDs outputs at Mission Level into TE concept aircraft models, and assessing impacts of IADP and TE concept aircraft at Airport and ATS Level. An efficient interfacing between TE and ITDs and IADPs will be established through dedicated work packages (TE WP2 and ITD/IADP TE work packages) taking also into account IPR and confidentiality issues.

ITDs will deliver inputs either to IADPs for integration into the concept vehicles to be forwarded to TE or (if no integration is foreseen) directly to TE (e.g. UHBR engine input to TE). Additionally, TE will perform design studies on long term innovative aircraft configurations. Benefits of transversal activities as Small Air Transport (SAT) and Eco-Design/Life-cycle Analysis (ED/LCA) will be monitored in a similar way as ITDs and IADPs. SAT and business jet concept aircraft will be performed in the Airframe ITD and be given as input to TE.

Figure 14.1: TE tasks and interfaces with ITDs and IADPs.
The work flow between TE and ITDs and IADPs can be characterized as follows (see also figure 14.2):

- Aircraft concepts from IADPs are integrated by the TE through black boxes into a fleet to be evaluated at Airport and ATS level;
- ITD technologies that are not to be integrated into IADP aircraft will be treated at TE Mission level via TE ac models (to be constructed in close cooperation and with input from industry) to be evaluated at airport and ATS level.
- Research partners of the TE in Clean Sky 2 work with their own models at mission level on long-term innovative aircraft concepts (e.g. Blended Wing Body). These TE concept aircraft are then also evaluated at Airport and ATS level.

Figure 14.2: Work flow between TE and ITD / IADPs.
14.4 TE assessment points and assessment areas

The following assessment points will be covered (see Figure 14.4):

1. Year 2015: this is the reference year technology, to which concept aircraft and rotorcraft will be compared. The reference aircraft and rotorcraft will thus be a year 2015 state of the art technology vehicle.

2. Year 2025: This is the time horizon for the IADP concept aircraft. There will also be TE 2025 concept aircraft, namely the large aircraft equipped with a UHBR.

3. Year 2035 and 2050: This is the time horizon for the TE concept aircrafts. These concept aircraft will be designed by the TE in interaction with ITDs and IADPs.

The following main comparisons will be performed:

- 2025 versus 2015
- 2035 versus 2015
- 2050 versus 2015

If necessary other combinations of the assessments points will be done as well as a comparison with 2000 technology aircraft where applicable.
The following assessment areas will be covered by the TE:

<table>
<thead>
<tr>
<th>Assessment area</th>
<th>Indicators</th>
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<tbody>
<tr>
<td>Gaseous emissions</td>
<td>Carbon dioxide (CO2) and fuel burn in tonnes</td>
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<tr>
<td></td>
<td>CO2 equivalents for life cycle assessments in tonnes</td>
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<tr>
<td></td>
<td>Oxides of nitrogen (Nox) in tonnes</td>
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<tr>
<td>Noise on ground</td>
<td>Acoustic levels in SEL, EPNL, Lden</td>
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<tr>
<td></td>
<td>Surface area of acoustic levels in square km</td>
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<tr>
<td></td>
<td>Number of People exposed to certain acoustic levels</td>
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<tr>
<td>Airport capacity and throughput</td>
<td>Delay of aircraft in minutes</td>
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<tr>
<td>Mobility and connectivity</td>
<td>e.g. Number of passengers</td>
</tr>
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</table>

Where possible, the progress of the Clean Sky technology performance at aircraft and fleet level towards ACARE goals (e.g. noise, emissions, 4 hours etc.) will be monitored and continuously reported. The Clean Sky technology performance progress will be monitored in terms of absolute and relative deltas, i.e.:

- Reduction of emissions/fuel in tons and in % (Mission, Airport and ATS level)
- Average noise reduction in dB, noise area reduction in square km and in % (Mission level)
- Noise area and noise exposed people reduction in square km, number of people and % (Airport level)
14.5 Work Breakdown Structure

The TE in Clean Sky 2 will have eight work packages. Whereas WP Level 1 reflects the TE workflow, each ITD, IADP and transversal activity is individually addressed at WP Level 2 in WP2 and WP3. Thus, a dedicated “coordinator” for the different vehicles is planned, considering the matrix structure (workflow vs. vehicles) of the TE.

14.5.1 TE Management – WP0

WP0 covers the management, i.e. the project administration and technical coordination. It includes the reporting to the JU as well as the organization of regular management meetings.
14.5.2 Scope and Setup of the TE – WP1

The overall scope and set-up of the TE is covered through WP1. Within this WP the methodology for evaluation on Mission Level and for impact assessment on Airport and ATS Levels will be defined, including the interdependencies between the three levels and the interactions with IADPs, ITDs, and transversal activities (WP1.1). The TE inputs and outputs will be defined (WP1.2). This comprises:

1. The inputs from the IADPs and ITDs:
   - The IADP aircraft models will be specified according to the TE requirements. The top Level Aircraft requirements will be defined for each IADP vehicle and the TE will also use these for TE aircraft model calibration purposes. Technology descriptions will be given providing information on what technologies are integrated in the aircraft model and at what TRL.
   - ITD inputs will be specified according to TE requirements e.g. the UHBR engine input.

2. The outputs of the TE:
   - Outputs of the TE will be defined at Mission, airport and ATS level indicating metrics to be used, airports to be covered and fleet scenarios and forecasts to be applied.

A detailed level of TE outputs and expected inputs from ITDs / IADPs /TAs will be defined together with the platforms in 2014-15, which includes a set common references, metrics and measurement techniques (concept aircraft and scenarios) to ensure the coherence between the modeling of the different concept aircraft (consistency check between TE Integration/Evaluation and In-House IADP evaluation).

The TE shall monitor the Clean Sky 2 achievements versus defined environmental and societal categories of objectives which are listed below:

- Clean Sky 2 high level and platforms environmental goals;
- Contributions to Climate impact mitigation, e.g. through climate optimized trajectories;
- Additional Clean Sky 2 objectives: Mobility/Connectivity, Productivity.

General output of the TE will be:

Mission level:
- TE 2035 and 2050 concept aircraft models for novel mid to long term innovative configurations (e.g. buried engines, blended-wing body);
- TE 2025 concept aircraft models covering direct ITDs input not delivered via IADPs (e.g. long range aircraft with ultra-high bypass ratio engine);
- Demonstrating progress with respect to objectives of individual IADP / ITD / TE aircrafts.

Airport level:
- Scenarios definition for generic and real airports;
- Generic and real airport impact assessments addressing, for instance, capacity constraints and time efficiency, noise and its psycho-acoustic effects, emissions and their contribution to local air quality.

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48 The planning of the assessment strategy is to be harmonised with the Clean Sky 2 Interim Assessment.
ATS level:
- Forecasts and scenarios for rotorcraft, business jet, small air transport, regional aircraft and mainliner’s fleets;
- Emission and noise inventories, including climate impacts, for mainliner, regional aircraft, business jet and small air transport;
- Emission and noise inventories for rotorcraft fleets;
- Socio-economic impacts (not including competitiveness) e.g. mobility/connectivity and employment plus GDP impact (where applicable).

Assessments will be carried about every 3 years (see Figure 14.5) according to the “drumbeat” of the IADPs, ITDs and TA (Eco-design and SAT) activities. The IAs will deliver models to the TE based on a number of development loops inside the IADP, ITD and TA, taking into account things like preliminary/critical design reviews and demonstration activities that will shape the content of the aircraft and rotorcraft simulation models to be delivered to the TE. After reception of the IAs models and taking into account also the TE internal models chains complete assessments will be performed in intervals of about three years. As can be seen in Figure 14.5, the 1\textsuperscript{st} two years will mainly cover the preparation activities (definition inputs /outputs, specification of aircraft models etc.) through work package 1, 3, 4 and 5.

Consistency with external projects, like PARTNER, SESAR and SESAR 2, (WP1.3), will be regularly checked and cross verification, if possible, applied. For instance innovative SESAR/SESAR 2 airport procedures, as available, will be integrated in airport impact assessments. SESAR scenarios and results on ATM en route efficiency improvements through SESAR/SESAR 2 will also be considered in ATS impact assessments as separate external layer, in order to support a common overview of both project impacts.

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<tr>
<th>*</th>
<th>means: milestone</th>
<th>Assessment</th>
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<td>WP1 Scope setup</td>
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<td>WP2 Interfacing</td>
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<td>WP3 ind. Int. mission level</td>
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<td>WP4 Airport</td>
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<td>WP5 ATS</td>
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<td>WP6 TE IS</td>
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<td>WP7 Diss</td>
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<tr>
<td>LPA model input (tbc)</td>
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<td>RIADP model input</td>
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<td>FRC model input</td>
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<td>Engine ITD input (baseline)</td>
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<td>Engine ITD input (UHBR)</td>
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<td>Systems ITD (tbc)</td>
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<td>Airframe (tbc)</td>
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<td>SAT (tbc)</td>
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Figure 14.5: TE milestones
WP 1
TE Scope and Set-up

WP 1.1
Methodology for evaluation, impact assessment and interdependencies

WP 1.2
Definition of TE inputs and outputs

WP 1.3
Consistency with respect to external projects

WP 1.4
Global workflow
14.5.3 TE Interfacing with IADPs, ITDs and Transversal Activities – WP2

WP2 covers the interfacing between the TE and the three ITDs, namely Airframe, Engine and Systems, and the IADPs, namely Large Passenger Aircraft, Regional Aircraft and Fast Rotorcraft. The interfacing includes the definition of trade-off studies and the progress monitoring of Clean Sky 2 achievements vs defined environmental and societal objectives. As can be seen in Figure 14.1 and as recommended by external reviewers, this means that an effective interfacing between TE and ITDs and IADPs will be established through dedicated work packages and Persons of Contact in the TE and the ITDs/IADPs and SAT and Eco-design:

- In TE: WP2
- In ITD/IADP/TAs:
  - LPA WP0.1: Technology assessment
  - RIADP WP 4.1: Technology assessment
  - FRC:
    - Tilt-rotor WP7: TE Interface
    - Life craft WP1.6: TE interface
- Airframe ITD: through “Interface & cross interaction management”
- Engine ITD: through “Interactions & interfaces with other ITDs/IADPs/TE” management
- Systems ITD WP 0.1: Interface with TE
- Transversal Activities: SAT and Eco Design: will be established

Special care has to be taken on the access to ITDs and IADPs foreground and background knowledge (i.e. IPR issues). The transversal activities Small Air Transport and Eco-Design are part of the ITDs and interfacing with TE will be assured.
14.5.4 TE Integration on Mission Level – WP3

In the course of the programme the following aircraft/rotorcraft models will be delivered to the TE through the IADPs, ITDs and SAT:

- LPA: Short and medium range aircraft
- RIADP: 2 regional aircraft configurations
- Airframe ITD: business jet aircraft
- FRC: A tilt-rotor and a compound rotorcraft configuration
- SAT: turboprop small aircraft

The models will allow the assessments at mission level according to the assessment points as explained in Chapter 14.4. Thus four time horizon vehicles will be applied and or developed in the TE:

1. Year 2015: this is the reference year technology, to which CS2 concept aircraft and rotorcraft will be compared. The reference aircraft and rotorcraft will thus be a year 2015 state of the art technology vehicle (either based on existing configurations or on generic ones) and be delivered to the TE. In case of own TE 2025 concept aircraft (see point # 2) the TE will develop its own 2015 reference aircraft. The TE will calibrate its own reference aircraft models according to the IADP reference aircraft main characteristics (e.g. Top level aircraft requirements and additional parameters as appropriate).

2. Year 2025: This is the time horizon for the CS2 concept aircraft, covering two sorts:
   - IADP 2025 concept aircraft models to be delivered to the TE
   - TE 2025 concept aircraft, e.g. the large aircraft equipped with a UHBR. The principle is that TE develops concept aircraft models integrating ITDs outputs from Airframe, Systems and Engine Level that are not to be integrated into IADP aircraft. This will be done in close interaction and regular iteration loops with the Airframe, Systems and Engine ITDs and technology “baskets” (see also point # 3 below) will be defined to be integrated into the TE models

3. Year 2035 and 2050: This is the time horizon for the TE mid to long term concept aircrafts (e.g. blended wing body or buried engines etc.). These concept aircraft will be designed by the TE also in interaction with ITDs and IADPs.
   - Taking into account and considering technologies that are developed in the ITDs (e.g. at low TRL levels) TE will define Technology “baskets” to be integrated in the 2035/50 concept aircraft configurations.

Comparisons against the set environmental goals between reference and concept aircraft and rotorcraft will be done.
TE concept aircraft modelling

Existing aircraft/rotorcraft models (conceptual level) that are currently used in Research Establishments and Universities and/or models used by industry will be used to design the TE concept aircraft, using inputs by Airframe, Engine and Systems ITDs that are not to be integrated into IADP aircrafts and using TE inputs for innovative mid to long term configurations (e.g. blended wing body).

Current state of the art in overall aircraft modelling includes multi-disciplinary optimization based on low-fidelity tools with punctual calls to advanced disciplinary analysis. Regarding the design of key components such as the wing, latest studies propose fully coupled optimizations with high fidelity tools considering aerodynamics and structural aspects.

In the TE modelling, the goal is to further develop these existing capabilities in order to explore and define more complete aircraft architectures earlier in the design process with more reliable data. To this goal, one of the tasks is to increase the number of disciplines (aero elasticity, controls, noise, emissions, operations, etc.) to be considered in the overall aircraft optimization. The second key aspect is to increase the fidelity of the analysis tools (FEM, CFD, etc.) and to adapt the optimization process to the associated increase of variables (continuous and discrete). Activities include then improvements of tools related to aeronautical disciplines and subsystems as well as developments in the design and simulation environment, optimization algorithms and knowledge management. In addition, the proposed work in the TE modelling is an opportunity to develop these design processes between various international partners, leading automatically to enhancements in the collaborative design between departments as well as separated entities. Key issues such as sharing of proprietary codes, standardized processes and uniformed database will thus be considered also.

Different levels of fidelity in the aircraft design will be applied. Level 0 is based on empiric models with data derived from pre-existing aircraft designs. Level 1 is characterized by a low order, physics based model (e.g. a beam representation of a structure). Depending on the discipline, higher order methods can be made available if the technologies under review demand a more detailed analysis. The level of fidelity will be adjusted to provide meaningful and reliable results under consideration of available resources (budget and time).
14.5.5 TE Airport Impact Assessments – WP4

The TE Airport Level concerns the air traffic movements at and around airports, including local airspace (e.g., control zones and terminal manoeuvring areas). It assesses the impact of ITD and IADP concept aircraft / rotorcraft but also the impact of TE concept aircraft (see 14.5.4 TE Integration on Mission level – WP3). The assessments aim to quantify the Clean Sky 2 benefits in terms of relevant environmental and societal impacts, including capacity and time efficiency, noise and its psycho-acoustic effects, emissions and their contribution to local air quality, and socio-economics (e.g. improved turnarounds). In addition to these assessments, TE Airport Level also conducts trade-off studies.

In WP4.1 the scenarios for TE Airport Impact Assessments will be defined. This definition will include the specification of the set of generic and real airports and (in particular for dedicated rotorcraft assessments) the set of generic and real city areas to be addressed. For these airports (and city areas) a distinction will be made between:

- Airports with only rotorcraft traffic, e.g., heliports and helipads in a city;
- Airports with only aircraft traffic, i.e., airports with mainly regional and mainliner air traffic;
- Airports with both aircraft and rotorcraft traffic, e.g., regional airports with mixed air traffic: Rotorcraft, small air transport, regional aircraft, and mainliner aircraft.

The scenario definition will also address the future airport operations and capacity constraints to consider, such as improved airport and flight operations resulting from SESAR and SESAR 2, and specify the air traffic, for instance, number of movements, types of missions, fleet composition, and flight schedules.

Based on the scenario definition in WP4.1, the subsequent sub-work packages will deal with performing the TE Airport Impact Assessments, including the necessary model and simulation platform enhancements. Hereby, Clean Sky 2 TE will capitalize on the models and simulation framework for Airport Level from Clean Sky TE.

The TE Airport Impact Assessments are built around three WPs, which are in accordance with the aforementioned subdivision of airports: Airports with only rotorcraft traffic in WP4.2, airports with only aircraft traffic in WP4.3, and airports with both rotorcraft and aircraft traffic in WP4.4. The activities in each of these WPs are structured similarly and address the following four main areas:

- Enhancement of airport models: To simulate the air traffic movements at and around the generic and real airports;
- Enhancement of environmental and societal impacts models: To quantify the Clean Sky 2 benefits (making use of IADP/ITD- and TE- concept aircraft / rotorcraft models, and the simulated air traffic);
- Enhancement of simulation framework: To perform in an integrated way the simulations and calculations for the TE Airport Impact Assessments;
- Impact assessment: To perform TE Airport Impact Assessments (and trade-off studies requested in WP2 by IADPs and ITDs), applying the aforementioned models and simulation framework.

A synthesis of the outcomes of the TE Airport Impact Assessments will be conducted and reported in WP4.5.
14.5.6 TE ATS Impact Assessments – WP5

WP5 covers the fleet and movement forecasts/scenarios and the TE Impact Assessments considering the global Air Transport System with respect to mainliners, regional aircraft, business jets, small air transport and rotorcraft. The ATS Level assesses the impact of ITD and IADP concept aircraft / rotorcraft TE concept aircraft (see 14.5.4 TE Integration on Mission level – WP3). The assessments aim to quantify the Clean Sky 2 benefits in terms of relevant environmental and societal impacts, including noise (e.g. for a representative set of EU airports), emissions, climate (via optimized trajectories) and socio-economics such as mobility/connectivity enhancements (e.g. ACARE 4h goal). ATS Level will also perform trade-off studies as appropriate.

Forecasts and fleet specific scenarios will be conducted for rotorcraft, business jet, small air transport, regional aircraft and mainliners fleets separately (WP5.1). Forecasts will be performed by the TE and through TE models for 2025, 2035 and 2050 time horizons. Scenarios will encompass a number of variations comprising:

- Aircraft and rotorcraft fleet and traffic mixes
- Realistic and generic Technology insertion in the fleet
- Generic airlines
- Small Air Transport fleet traffic and related small airport infrastructure in the world
- ATM efficiency
- Climate impact reduction through climate optimized trajectories
- Connectivity and mobility (e.g. feeder services to bigger hubs)
- Rotorcraft fleet traffic and Heliport infrastructure in the world
- Capacity constraints

According to these scenarios emission inventories will be performed for the mainliner fleet, regional aircraft, the business jet and small air transport fleet in WP5.2 separately. European noise inventories for the biggest European airports (covering ~90% of noise annoyance) will also be elaborated.
Emission and noise inventories for rotorcraft fleets will be performed separately in WP5.3.

The activities in WP5.2 and WP5.3 are structured similarly and address the following four main areas:

- Enhancement of ATS models: To forecast global fleet movements and simulate under different scenario conditions;
- Enhancement of environmental and societal impact models: To quantify the Clean Sky 2 benefits (making use of IADP/ITD- and TE- concept aircraft / rotorcraft models, and the simulated global fleet traffic);
- Enhancement of simulation framework: To perform in an integrated way the simulations and calculations for the TE ATS Impact Assessments;
- Impact assessment: To perform ATS Impact Assessments and trade-off studies applying the aforementioned models and simulation framework.

A synthesis of the outcomes of the ATS Impact Assessments will be conducted and reported in WP5.4.
14.5.7 TE Information System – WP6

WP6 covers the TE Information System (TE-IS). The TE-IS is a framework (WP6.1) that is built on top of the three simulation platforms from WP3, WP4, and WP5 (namely, the simulation platform for Mission Level, Airport Level, and ATS Level, respectively) as shown in Figure 14.6. The TE-IS database (WP6.2) contains raw data and all assessment results. A reporting system (WP6.3) permits the user to get selected result reports based on personalized queries according to given parameters (e.g. for fleet: Seat categories, origin destination, pressure altitude, fleet scenario, emission type). The functionalities of the TE-IS will be enhanced with respect to the degree of freedom in personalized queries at all TE platform levels. Other features to be worked on are reporting and visualization of outputs (see Figure 14.7).
14.5.8 TE Dissemination – WP7

WP7 covers the internal and external dissemination which will be based on the TE assessment results. WP7.1 deals with dissemination inside the Clean Sky 2 Programme and WP7.2 with external dissemination of achievements and progress to a wider public. Both dissemination activities are done in close consultation with the JU and the ITDs / IADP / TAs through the TE Steering Committee. The internal dissemination will focus on providing feedback with respect to technology impacts on the three assessment levels. The external dissemination needs to be stakeholder specific (European Commission, public, scientific community, aviation stakeholders) and TE will provide related material to support JU in the external communication.
14.5.9 Overview of the Work Breakdown Structure:

WP 0 TE Management
  0.1 Administration & Coordination
  0.2 Meetings
  0.3 Administrative Reporting

WP 1 TE Scope and Set-up
  1.1 Methodology for evaluation, impact assessment and interdependencies
  1.2 Definition of TE inputs and outputs (incl. definition of metrics where necessary)
  1.3 Consistency with respect to external projects
  1.4 Global workflow

WP 2 TE interfacing with IADPs, ITDs and Transversal Activities
  2.1 IADP: Regional Aircraft
  2.2 IADP: Large Passenger Aircraft
  2.3 IADP: Fast Rotorcraft
  2.4 ITD: Airframe
  2.5 ITD: Engine
  2.6 ITD: Systems
  2.7 Transversal: Small Air Transport
  2.8 Transversal: Eco-design
  2.9 Overall interface efficiency and risk management

WP 3 TE Independent Integration on Mission Level
  3.1 IADPs
  3.2 ITDs
  3.3 Innovative concept aircraft modelling
  3.4 Transversal: Eco
  3.5 Transversal: SAT
  3.6 Synthesis

WP 4 TE Airport Impact Assessments
  4.1 Scenarios and Airport Capacity Constraints
  4.2 Heliports/helispots with Rotorcraft Traffic
  4.3 Airports with Aircraft Traffic
  4.4 Airports with Rotorcraft and Aircraft Traffic
  4.5 Synthesis

WP 5 TE ATS Impact Assessments
  5.1 Forecasts, Scenarios and Airport Capacity Constraints
  5.2 World-wide/Region and Aircraft (incl. SAT)
  5.3 World-wide/Region and Rotorcraft
  5.4 Synthesis

WP 6 TE Information System
  6.1 TE IS Framework
  6.2 TE IS Database
  6.3 TE IS Dynamic Reporting

WP 7 TE Dissemination
  7.1 Contribution to Internal Clean Sky 2 Reporting
  7.2 Contribution to External Reporting and Communication
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