Clean Sky at a Glance

Bringing Sustainable Air Transport Closer

February 2012
Introduction

Clean Sky is a Joint Technology Initiative (JTI) that aims to develop and mature breakthrough ‘clean technologies’ for Air Transport. By accelerating their deployment, the JTI will contribute to Europe’s strategic environmental and social priorities, and simultaneously promote competitiveness and sustainable economic growth.

Joint Technology Initiatives are specific large scale research projects created by the European Commission within the 7th Framework Programme (FP7) in order to allow the achievement of ambitious and complex research goals. Set up as a Public Private Partnership between the European Commission and the European aeronautical industry, Clean Sky will pull together the formidable research and technology resources of the European Union in a coherent, 7-year, €1.6 bn programme. It will contribute significantly to the ‘greening’ of aviation: an essential part of today’s global society, bringing people and cultures together and creating economic growth.

The Clean Sky goal is to identify, develop and validate the key technologies necessary to achieve major steps towards the ACARE\(^1\) environmental goals for 2020 when compared to 2000 levels:

- Fuel consumption and carbon dioxide (CO\(_2\)) emissions reduced by 50%
- Nitrous oxides (NO\(_x\)) emissions reduced by 80%
- Perceived external noise reduction of 50%
- Improved environmental impact of the lifecycle of aircraft and related products.

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\(^1\) Advisory Council for Aeronautics Research in Europe
Technologies, Concept Aircraft and Demonstration Programmes form the three complementary instruments used by Clean Sky in meeting these goals:

**Technologies** are selected, developed and monitored in terms maturity, or ‘technology readiness level’ (TRL). A detailed list of more than one hundred key technologies has been set. The technologies developed by Clean Sky will cover all major segments of commercial aircraft.

**Concept Aircraft** are design studies dedicated to integrating technologies into a viable conceptual configuration. They cover a broad range of aircraft: business jets, regional and large commercial aircraft, as well as rotorcraft. They are categorised in order to represent the major future aircraft families. Clean Sky’s environmental results will be measured and reported principally by comparing these Concept Aircraft to existing aircraft, and aircraft incorporating ‘evolutionary technology’ in the world fleet.

**Demonstration Programmes** include physical demonstrators that integrate several technologies at a larger ‘system’ or aircraft level, and validate their feasibility in operating conditions. This helps determine the true potential of the technologies and enables a realistic environmental assessment. Demonstrations enable technologies to reach a higher level of maturity (TRL). The ultimate goal of Clean Sky is to achieve TRLs corresponding to successful demonstration in a relevant operating environment. This is the highest TRL achievable in research.
Concept Aircraft will enable assessment of the environmental benefits of Clean Sky technologies across nearly the full spectrum of commercial aviation. Some key configurations that will be developed follow below.

**Business Jet Concept Aircraft**

- **Low Speed Business Jet:**
  This concept aircraft includes a low-drag laminar flow wing with low speed, and will feature a radically redesigned rear empennage. This innovative empennage aims to drastically reduce the community noise by shielding noise from the future generation turbofan engine with elements of the horizontal and vertical tail plane.

- **High Speed Business Jet:**
  This concept aircraft includes a ‘smart’ low-drag, highly swept wing design, making use of passive and active laminar flow. The wing’s high speed design aims to include a “smart flap” concept. New environmentally friendly materials and processes as well as new flight trajectories will be included.

**Regional Concept Aircraft**

- **Regional Turboprop:**
  The 90-passenger Regional Turboprop Aircraft represents a concept for a next generation ‘turboprop’ that could enter into service in 2020-2025. It features advanced technologies in almost all sub-systems: low weight structure, extensive use of electrical power in systems (bleed-less engine), and advanced flight management systems. A substantial reduction of the environmental impact will be achievable.

- **Regional Jet**
  The 130-passenger Regional Jet Aircraft is a concept aircraft that could likewise have an entry into service around 2020-2025. By utilising a next generation power-plant (Open Rotor or Advanced Geared Turbofan), and similar advanced technologies in sub-systems, it too will deliver superior environmental performance.
Large Commercial Concept Aircraft

- **Short / Medium Range Aircraft, Open Rotor:**
  This concept aircraft includes the all new ‘smart’ laminar-flow wing and key enabling technologies to design, manufacture and operate this. The concept aircraft will incorporate the Clean Sky Contra Rotating Open Rotor (CROR) engine concepts; subsequent flight-testing of a full size CROR engine demonstrator in the demonstration programme will aid in determining the full potential and maturity of the propulsion architecture. Advanced systems and new flight trajectories are planned to be included into the architecture.

- **Long Range Aircraft, Next Generation Large Turbofan:**
  The long range aircraft concept will provide the vehicle level platform to integrate the next generation large three shaft turbofan engine using Clean Sky technologies. It should be noted that major new long range aircraft will have entered the world fleet by 2015\(^2\), and therefore no new aircraft introductions are likely in the 2020 timeframe. Thus, the focus of Clean Sky in this aircraft category is predominantly on improved engines and systems.

\(^2\) E.g. Airbus A350 Family
Rotorcraft: Concept Aircraft

- Light Single-engine Helicopter:
The light single engine helicopter concept is equipped with future generation single turboshaft or with a Diesel piston engine, with optimised engine installations respectively. Superior performance is further enhanced by incorporating the latest innovative active blade technologies and applying radical redesign to empennage, skids and hub.

- Light/Medium/Heavy Multi-engine helicopter:
Generic light, medium and heavy concept helicopters are equipped with two or three future generation turboshaft with optimised engine installations. Their performance is further enhanced by incorporating the latest innovative active blade technologies, radical structural redesign, and the introduction of advanced electrical systems (including electric tail rotor) for the elimination of noxious hydraulic fluid and reduced fuel consumption.

- Tilt-Rotor:
The conceptual tilt-rotor aircraft is based on the European ERICA\(^3\) tilt-rotor concept, characterised by a small rotor diameter and tiltable wing. Performance is enhanced by aerodynamic optimisation and the installation of a future generation turbo-shaft engine.

\(^3\) ERICA: Enhanced Rotorcraft Innovative Concept Achievement – FP5/6
The environmental objectives of the programme are determined by evaluating the performance of concept aircraft in the global air transport system (when compared to 2000 level technology and to a “business as usual” evolution of technology). The ranges of potential improvements result from the groupings of technologies which are expected to reach the maturity of a successful demonstration within the programme timeframe. Not all of these technologies will be developed directly through the Clean Sky programme. But it is neither feasible nor relevant at this stage to isolate the benefits derived purely from Clean Sky. A significant synergy effect in European Aeronautics Research is made possible, through Clean Sky, by maturing closely linked technologies to a materially higher TRL via demonstration and integration.

![Graph showing CO2 Reduction Potential (2020 Technologies, %)](image)

The environmental performance gains we expect to see confirmed through demonstration of the technologies are depicted in these graphs. They are representative figures across the different aircraft types and sectors (business jets, regional aircraft, large commercial aircraft and rotorcraft). There is broad similarity between the improvements foreseen across these different aircraft types despite the different modes of operation and the different technologies involved.

Nonetheless, some specific opportunities and challenges should be mentioned.

In the business jet sector, the potential use of a novel, radical re-design of the empennage (tail surfaces) could aid in shielding noise from the engines and further reduce community noise. As these aircraft often operate into very noise-sensitive local airports this design option will be elaborated further, potentially augmenting the gains that are feasible.
In large commercial and regional jet aircraft, a key design option concerns the incorporation of the Counter Rotating Open Rotor (CROR) engine architecture and technology. This design option involves an important trade-off: significantly more fuel burn and CO₂ reductions are expected, coupled with less progress on noise, when compared to future turbofan architectures. The figures in these graphs assume the use of CROR on short/medium haul aircraft. Fixed wing aircraft figures represent the median performance improvement across the spectrum of business jets, regional aircraft and short/medium range commercial aircraft. Long-range commercial aircraft are, as yet, not included as no (integrated) concept aircraft predictions are available.

In rotorcraft, an innovation being investigated concerns the adoption of Diesel engine propulsion (on so-called light single-engine helicopters). The Diesel engine could deliver impressive fuel burn and CO₂ benefits, albeit with a penalty in NOₓ performance when compared to a future turboshaft engine. The graphs depict the range of variance this would imply for both CO₂ and NOₓ.

Note: noise reduction is measured in Effective Perceived Noise (EPNdB), and figures represent the average reduction per operation (take-off, approach or fly-past). A reduction of 10 EPNdB is widely accepted as corresponding to a halving of perceived noise in terms of the human auditory capacity and perception. The ACARE target of 'halving perceived noise' thus corresponds with a figure in the graph of -10 EPNdB.
Demonstration programme

While some technologies can be assessed during their development phase, many key technologies will need to be validated via dedicated test programmes, involving in-flight or large-scale ground demonstration installations. These demonstrators combine several technologies at a major system or at aircraft level, enabling them to be tested in a relevant operating environment. Their performance is evaluated in areas such as mechanical or in-flight behaviour. This will help to determine the true potential of the technologies and to enable a realistic environmental assessment. Demonstrations enable technologies to reach a higher level of maturity (TRL), which is the “raison d’être” of Clean Sky as a ‘Level 3’ highly integrated project and Joint Technology Initiative within the European Framework Research and Innovation Programme.

Contra Rotating Open Rotor (CROR) Demo Engine Flying Test Bed

- New propeller design (high performance, low noise)
- Engine - Pylon – Aircraft integration concept
- New CROR – Engine integration technology
- Advanced CROR aero-acoustic design

High Speed Demonstrator for passive laminar-flow wing technologies

- Advanced passive laminar wing aerodynamic design
- Two alternative integrated structural concepts for a laminar wing
- High quality, low tolerance manufacturing and repair techniques
- Anti contamination surface coating
- Shielding Krüger high lift device

Low Speed Demonstrator for advanced control surfaces for high lift

- Smart flap concept, with combined function for manoeuvre control and high lift
- Active flow control at the leading edge to replace slats
- Active flow control flaps for increased high lift performance
Regional Aircraft Integrated Flight Test Demonstration

☑ Advanced metallic & composite structure
☑ Structural health monitoring
☑ Electrical environmental control system
☑ Hybrid wing ice protection system
☑ Application and scaling of more-electric technologies and power management for regional aircraft

Q3/2015

Regional Aircraft Static & Fatigue Full Scale Ground Demonstration

☑ Advanced Al-Li structures and processes
☑ Multi-functional composite materials

Q2/2015

Regional Aircraft Large Scale Wind Tunnel Test Rotorcraft lift & drag demonstrators

☑ Turbulent flow skin friction reduction
☑ Natural laminar flow wing
☑ Load control / alleviation
☑ Low noise landing gears
☑ Low noise high lift devices

Q2/2015
Rotorcraft lift & drag demonstrators

- Innovative rotor blades:
  - Active twist blade and Gurney flap rotor
  - 3-D blade profile optimised for dual speed rotor
- Shape optimisation and flow separation control devices enabling drag reduction

Diesel engine demonstrator for light helicopters

- Core Diesel engine design
- Power-pack integration

Aircraft & Rotorcraft Systems Demonstrators

- Technologies for flight path optimisation

- Technologies for «All-Electric» architectures
- Environmental control systems
- Electrical actuation
- Nacelle-based systems
- Anti-ice
- Electrical wheel drive/taxiing
- Rotorcraft: electrical main rotor actuators
- Rotorcraft: electrical tail rotor
Geared Open Rotor Demonstrator

- Propeller/Propulsor
- Pitch change mechanism
- Gear-box
- Rotating structure

Q4/2015

Large Three-shaft Engine Demonstrator

- Lightweight fan system
- Advanced external engine components and accessories
- Advanced ‘intercase’ structures
- Lightweight and efficient low-pressure turbine

Q2/2013

Advanced Geared Turbofan Demonstrator

- Advanced Geared Turbofan Demonstrator
- New highly efficient high-pressure compressor
- Light weight, high speed low-pressure turbine
- Advanced light weight and efficient turbine structures
- Light weight and reliable fan drive gear system
- New systems for a more electric engine

Q4/2013

Advanced Turboshaft Demonstrator

- High efficiency compressor, combustion chamber, high-pressure and low-pressure turbine
- Full scale & life cycle validation

Q1/2013
Clean Sky activities are performed within six “Integrated Technology Demonstrators” (ITDs) and a “Technology Evaluator”. The organisation is shown in the following figure.

The three vehicle-based ITDs will develop, deliver and integrate technologies into concrete aircraft configurations. The three ‘transversal’ ITDs are focused on propulsion, systems and design methodologies. They will deliver technologies, which will be integrated alongside aircraft-level and ‘airframe’ based technologies in the various aircraft configurations by the vehicle ITDs.

**Smart Fixed Wing Aircraft (SFWA)** – co-led by Airbus and SAAB - will deliver innovative wing technologies together with new aircraft configurations, covering large aircraft and business jets. Key enabling technologies from the transversal ITDs, for instance Contra Rotating Open Rotor, will be integrated into the demonstration programmes and concept aircraft.

**Green Regional Aircraft (GRA)** – co-led by Alenia and EADS CASA - will develop new technologies for the reduction of noise and emissions, in particular advanced low-weight & high performance structures, incorporation of all-electric systems, bleed-less engine architecture, low noise / high efficiency aerodynamics, and environmentally optimised mission and trajectory management.
Green Rotorcraft (GRC) – co-led by AgustaWestland and Eurocopter - will deliver innovative rotor blade technologies for reduction in rotor noise and power consumption, technologies for lower airframe drag, environmentally friendly flight paths, the integration of Diesel engine technology, and advanced electrical systems for elimination of hydraulic fluid and for improved fuel consumption.

Sustainable and Green Engines (SAGE) – co-led by Rolls-Royce and Safran - will design and build five engine demonstrators to integrate technologies for low fuel consumption, whilst reducing noise levels and nitrous oxides. The ‘Open Rotor’ is the target of two demonstrators. The others address geared turbofan technology, low pressure stages of a three-shaft engine and a new turboshaft engine for helicopters.

Systems for Green Operations (SGO) – co-led by Liebherr and Thales - will focus on all-electrical aircraft equipment and system architectures, thermal management, capabilities for environmentally-friendly trajectories and missions, and improved ground operations to give any aircraft the capability to fully exploit the benefits of the ‘Single European Sky’.

Eco-Design (ECO) – co-led by Dassault Aviation and Fraunhofer Gesellschaft – will support the ITDs with environmental impact analysis of the product life-cycle. Eco-Design will focus on green design and production, maintenance, withdrawal, and recycling of aircraft. The optimal use of raw materials and energies, avoidance of hazardous materials, and the reduction of non-renewable energy consumptions of systems on-board will help to considerably reduce the environmental impact of the aircraft and its systems.

Complementing these six ITDs, the Technology Evaluator (TE) is a dedicated evaluation platform cross-positioned within the Clean Sky programme structure. The TE is co-led by DLR and Thales, and includes the major European aeronautical research organisations. It will assess the environmental impact of the technologies developed by the ITDs and integrated into the concept aircraft. By doing this, the TE will enable Clean Sky to measure and report the level of success in achieving the environmental objectives, and in contributing towards the ACARE environmental goals. Besides a mission level analysis (aircraft level), the positive impact of the Clean Sky technologies, will be shown within an airport environment and across the global air transport system.
The first assessment by the Technology Evaluator on the way to meeting our environmental objectives has been completed in early 2012 and results broadly confirm the objectives set for the programme.

The ranges of potential performance improvement (reduction in CO₂, NOx and Noise) will be narrowed or evolved during the life of the programme based on the results from the key technologies developed and validated through the demonstrations performed.

Clean Sky is a ‘living’ programme: each year, Annual Implementation Plans are produced and agreed, and research priorities are (re-)calibrated based on results achieved. The best approach to progressing the technologies is pursued. The Clean Sky JU uses regular Calls for Proposals to engage with the wider aeronautical industry, research organisations and universities in order to bring the best talent on-board and enable broad collaborative participation. A very significant share of the Clean Sky research programme is already being taken on by Europe’s aerospace related SMEs, and in January 2012 the 11th Call for Proposal was launched. In June 2011, a major and exciting milestone was reached with the 400th partner joining the Clean Sky programme.

For organisations interested in further information on Clean Sky, or becoming involved in the Programme, regular updates are published on www.cleansky.eu

There, further information is available on the programme’s research topics, and the selection criteria and process for participating, such as the Calls for Proposals.