Trajectory Optimization over the 4DWeatherCube

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To see more about the project, following the links below...

- https://vimeo.com/153516896
When MET Service Providers...

In the frame of the SESAR program, the EUMETNET consortium members* have collaborated to deliver the meteorological brick of the overall SESAR architecture: The 4DWeatherCube. The high level objective was to propose an easy way to access pan European meteorological services and guarantee the best possible quality in the information provided.

Four key success criteria were pursued: a single access point for Europe, a consistent seamless vision of MET across Europe and beyond, fit-for-purpose MET information and SWIM Compliance. Designed as the one stop shop for MET, the 4DWeatherCube provides 8 SWIM services from classical regulated products to European harmonised products related to latest scientific fields such as convection, icing and clear air turbulence.

In the beginning of 2015, those services have been exposed to the ATM industry in the frame of the SWIM Master Class to enable the development of innovative ATM applications in line with the ATM Master Plan objectives.

...meet industry leaders

Considering the increasing number of flights in the Single European Sky AIRBUS Defence and Space together with Luciad and EUMETNET developed a solution to help ATM operators in optimizing Trajectories and Airspace. The SES Optimization Solution which is an initiative out of the SWIM Master Classes 2014 and 2015, is a SWIM - based service and application to support ATM stakeholders in the effort to reduce aviation’s impact to the Earths’ environment whilst gaining maximum ATM network performance. The solution is in line with SESAR's prime objectives “Saving flight time (8 to 14 minutes average per flight) fuel and CO₂” and “Reduction of environmental impact by 10% per flight”

The SWIM Master Class awards recognized the technical and innovative achievement in the field of applications (2014) and services (2015).

As we move to operations and business, the Single European Sky award is the occasion to gain visibility about our partnership.

* In SESAR II.2.2 Météo-France, Met Office and Deutscher Wetterdienst (DWD) cooperates under EUMETNET aegis

> Short description of the project

Query MET data over time
See the impact on the ATM system in real-time
### SES Award Criteria

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<th>SES Award Criteria</th>
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<td><strong>1- Contribution to increasing capacity of ATM systems</strong></td>
<td>4DWeatherCube enables a precise and shared view of weather information which can help to better organise the airspace and therefore increase capacity. Optimising 4D trajectories and coordinating well with needed static airspace reservations based on 4D weather data also enables increase in capacity. During several SESAR Validation Exercises (VP 710, VP774 and VP789) a reduction of flight distance / fuel and CO₂ production (by -65.4 nm, -495 kg (fuel) and -1.554 kg (CO₂)) could be gained in a predefined scenario. Shorter flights mean a gain of capacity. The scope of the validation exercises was different, but the tools, systems and procedures were equal to the ones used in this partnership.</td>
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<td><strong>2- Contribution to increasing safety of ATM systems</strong></td>
<td>4DWeather cube enables the in time delivery of weather hazards (convection, icing and clear air turbulence) to the ATM users and therefore contributes to increase safety. The shared consistent vision of hazardous Weather across Europe is also improving safety. This applies during the planning and execution phase of all flights.</td>
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<td><strong>3- Contribution to reducing ATM costs</strong></td>
<td>By enabling optimization of 4D trajectories, the solution contributes to a reduction of flight time. In this way usage of the SES can be further optimized. Advanced optimisation by reduction of conflicts between 4D trajectories and airspaces helps in minimizing flight distances. Early foreseeing and avoiding hazardous weather phenomenon also reduces necessary rerouting. Less flight time in consequence leads to less controlling time which helps to reduce ATM costs. Furthermore a noticeable improvement in planning and managing workflows of ATM operators (e.g. Flight Planners, Mission Planners, FlightPlan Operators (IFPS), Airspace Managers) will be gained by integrating the applications and services provided by the partners Airbus Defence and Space, Luciad and EUMETNET. The implementation of the “Optimizing trajectories over the 4DWeatherCube” solution is fully in line with latest Master Plan and concepts of SESAR. Using this cutting edge technology to manage 4D trajectories and airspace in the SES, along with environmental information at the same time, will clearly increase planning speed. Workflows and collaborative decision making can be much faster. This will increase the speed and quality of decision making for the operators and that also will in turn lead to a reduction in ATM costs. Hence the solution “Optimizing trajectories over the 4DWeatherCube” can be seen as an enabler to save ATM costs.</td>
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<td><strong>4- Contribution to reducing the impact of air transport on the environment</strong></td>
<td>Today aircraft operators optimize their flights according to current rules and regulations to be most efficient in their flight planning and execution. Our solution supports aviation partners in optimizing the network gain additional performance. By enabling optimization of 4D trajectories the solution contributes to a reduction of flight time. A reduction in flight time in turn leads to a decrease in fuel consumption and therefore less CO₂ emission. In this way air transport can benefit and at the same time reduce impact on Earth’s environment. A field of innovation we have explored is contrails. Contrary to the CO₂ emission, this topic is not yet regulated by ICAO. Research studies show that contrails emitted by aviation contribute to the global warming. Our solution proposes to quantify and minimize the impact of contrails on environment. By creating a measuring tool for contrails impact, we will open the way for further trade off between efficiency and green flight. Another aspect of our solution is the capability of on-the-fly use of weather information enabled by real time meteorological services. The 4DWeatherCube services provide current but also forecast information, which is the basis of our trajectory optimization calculations. By avoiding hazardous weather areas (like storms or ash clouds, etc.) critical situations which endanger aircraft in flight can be reduced. Guiding aviators safely to destination also helps to avoid negative impact to the aircraft and environment.</td>
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<td>**5- Early implementation («First mover»)»</td>
<td>The solution has been based on open standards, known formats and proven technology. Furthermore interfaces with existing (fielded) systems and products showed already the benefit and further potential. A prototype of the solution “Optimizing trajectories over the 4DweatherCube” can be seen on the World ATM Congress (Madrid, 2016). The basis technology coming from Luciad is already implemented in a service-oriented way and can be made available elsewhere via internet. Interfaces to existing systems were well recognized from partners (mainly from Eurocontrol and the Military) during different Validation Exercises within SESAR (see also point 1. “capacity”).</td>
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<td><strong>6- Potential to be replicated over the ATM network</strong></td>
<td>The 4DWeatherCube concept originates from NextGen: Its principles have been adopted in various regions of the world. The 4DWeatherCube provides a single logical point of access for all meteorological information in Europe. The final physical architecture has not yet been decided. The foreseen architecture allows the software to be replicated and deployed among several physical locations for redundancy. A key principle of the design was an open architecture which can integrate easily weather information delivered by multiple Meteorological Service Providers. To ease global deployment, the proposed applications using the 4DWeatherCube are all cross-platform and built entirely upon SWIM standards and services.</td>
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<td><strong>7- Innovative aspects</strong></td>
<td>The solution proposed is fully compliant with SESAR standards (SWIM). A special effort has been put on the performances as meteorological information deals with “Big Data”. Combination of different sources of information (i.e. Meteo- rological Data, Flight Plan data (Network Manager), Airspace Data (Airspace Manager)) combined with an easy-to-un- derstand visualisation has been the key to the innovative solution developed by Airbus Defence and Space, Luciad and EUMETNET. Innovative aspects of our solution have been recognized by the community through the SWIM Master Class awards 2014 [Application] and 2015 [Service].</td>
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<td><strong>8- Promoting partnerships</strong></td>
<td>Classical relationship of MET Service Providers is with their respective ANSPs through regulated products. Thanks to SESAR, MET products straight out of science have been proposed to the industry for innovation. The partnership between Airbus Defence and Space with Luciad formed during SMC 2014, has been very beneficial in marketing aspects for both sides. Several presentations and demos where executed in Germany, Belgium, France and Spain. The solution has always been well recognized by the spectators. Main Contribution from Airbus Defence and Space has been ATM knowledge and operational experience in Aviation plus implementation of interfaces between ATM domain (Network Manager, Airspace Manager) and operation support systems. Luciad brought its state-of-the-art geospatial software solution, including hardware-accelerated components to perform on-the-fly 4D visual analytics on large amounts of data and components to work with and deploy SWIM-enabled standards and services. EUMETNET joined the partnership in 2015 with its 4DWeatherCube solution. MET products have been integrated to extend the solution to address the environmental aspect of flight optimisation.</td>
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<td><strong>10- Promoting SES and SESAR beyond the Union’s boundaries</strong></td>
<td>SESAR 4DWeatherCube is an active partner of the SWIM global demonstration planned for June2016. Through this activity, EUMETNET ensures coordination with other regional MET Service Providers such as US, Australia, Dubai... In the frame of future SESAR activities, we will enhance the coordination between regional MET Service Providers at a global level.</td>
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Airbus Defence and Space is Europe’s largest and most innovative defence and space company. We develop and manufacture world-class aerospace products. Our exceptional platforms and services allow our customers to address even their most challenging operational needs. Airbus Defence and Space drives the market in Defence and Space:
> Future-proof with growth in order intake, a strong order book above € 40 bn and ca. one third of revenues in services
> Investing in growth with an R&D spent 2014 at € 360 M, 4.7% more than 2013
> Europe’s #1 in defence and space with € 13 bn revenues in 2014
> 38,000 people with more than 80 different nationalities working together
> Around the world at almost 100 sites across 24 countries

Airbus Defence and Space currently participates in the SESAR programme, developing the future 4D Mission Trajectory concept under WP11.01 as partner in the fly4D consortium together with Airbus Group, Sabre, Lufthansa Systems and Honeywell.

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Luciad

> World experts in real-time situational awareness geospatial software components. Luciad builds software components that allow developers to deliver geospatial situational awareness applications
  - Luciad is valued for high performance fusion, visualization, and analysis of large volumes of static and dynamic data, maps, satellite imagery and terrain elevation in many different formats and references
> Strong focus on Aviation
  - Support for a wide range of aeronautical standards and data formats
  - Long-time supporter and implementer of SWIM-enabled standards and services
  - Participating member in OGC Aviation and SESAR-related research initiatives
  - Applications include Aeronautical Data Quality and Data Validation, Aeronautical Mapping Database Management, Flight Planning and Tracking, Central Flow Management, Air Command & Control, Electronic Flight Bags and En-Route Systems
> Cross-platform
  - Browser, desktop, server, mobile

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EUMETNET is a grouping of 31 European National Meteorological Services that provides a framework to organise co-operative programmes between its Members in the various fields of basic meteorological activities.

The 4DWeatherCube presented was developed in SESAR task II.2.2.2.

For the SES Award 2016, MET Office, DWD and Météo-France participate under the aegis of EUMETNET. Météo-France leads the proposal for this competition.

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Airbus Defence and Space and LUCIAD, winners of the SESAR SWIM MASTER CLASS Best-in-Class 2014

11/12/2014

Services and applications enabling distance calculations, aircraft tracking and optimised use of airspace have received top prizes at the 2014 SESAR SWIM Master Class Awards. The winners, which were announced during a Best-in-Class ceremony at Eurocontrol headquarters in Brussels, were among 39 SWIM-enabled ATM information solutions that were submitted to the Master Class jury for nomination in three categories: services, applications and technical infrastructure. The ceremony also demonstrated live some 20 services and applications, illustrating that SWIM is quickly becoming a reality within the global ATM system.

*From left to right: Wolfgang Schuecher (SOLITEC), Dirk Schindler (Airbus Defence & Space), Dario Di Crescenzo (Solex ES), Frank Saykens (Luciad), Vito Post (SESAR Joint Undertaking)

Meanwhile, the Best in Class award in the Applications category went to the Collaborative Airspace Provision Service, submitted by Airbus Defence and Space, together with Luciad. A runner-up prize was awarded to Luciad, Vito and Flight Plus for their platform on Remotely-Piloted Aircraft Systems Very Low Level Operation Coordination (RPAS VLLOC).
EUMETNET, winner of the SESAR SWIM MASTER CLASS Best-in-Class 2015

SESAR SWIM Master Class 2015 winners announced

10.12.2015

BRUSSELS, 10 December 2015 – System-wide information management (SWIM) solutions in the areas of civil-military collaborative decision-making and enhanced meteorological information provision have received top prices at the 2015 SESAR SWIM Master Class Awards. The winners – which were announced during a Best-in-Class ceremony at Eurocontrol headquarters in Brussels – were among 30 SWIM-...

European partners create single source of weather data

Phillip Butternworth-Hayes, London - IHS Jane’s Airport Review
15 December 2016

EUMETNET, a group of 31 European national meteorological services, won the Best-in-Class award in the information services category with its 4D WeatherCube in the 2015 Single European Sky ATM Research system-wide information management (SWIM) Master Class Awards, announced on 10 December 2015.

By integrating real time and forecast information from national weather centres throughout Europe, the 4D WeatherCube presents a consolidated and harmonised view, translatable into several different data formats and compatible with SWIM-compliant web services.

“The prototype is now ready for industrialisation,” said Kamil Rebol, head of the Development and Studies Department at Meleo France, “and we are working on ways to see how to certify the concept for air traffic management.”

To read the full article, Client Login
Monday, December 21, 2015

SESAR Seeing Increased SWIM Innovation Through Master Class

Woodrow Bellamy III

The recent completion of the fourth edition of the Single European Sky ATM Research (SESAR) Joint Undertaking’s System Wide Information Management (SWIM) Master Class shows that various aviation stakeholders are increasingly becoming aware of the SWIM concept and its practical usage in enhancing Air Traffic Management (ATM). According to SESAR, the Master Class has become an important global platform to build a critical mass of knowledge about SWIM and to help translate the concept into real world solutions.

The International Civil Aviation Organization’s (ICAO) SWIM concept manual describes SWIM as a “significant change in the business practices of managing information during the entire life cycle of an ATM process.” The goal of the SWIM concept of operations for SESAR, the FAA and others is to create a net-centric ATM platform that provides quality information to the right people with the right systems at the right time. These stakeholders include airline flight dispatch teams, air traffic controllers, pilots and more. Effectively, the SWIM environment will shift the ATM information architecture from point-to-point data exchanges to system wide interoperability.

In Europe, Eurocontrol has already deployed the basic ground-to-ground information management and distribution platform and infrastructure to enable what the future SWIM concept of operations will look like under a Single European Sky. With the SWIM Master Class, SESAR JU provides a jury of aeronautical technical experts that considers SWIM-enabled ATM information solutions under three categories: services, applications, and technical infrastructure. Earlier this month in Brussels, the fourth edition of the SWIM Master Class ended with a ceremony that featured 18 live demonstrations of services and applications showing what the future of SWIM could look like.

“Now that the data is becoming increasingly available, people start to discover what they can do with it, going from RPAS geo-fencing applications to innovative weather data being used in ATC simulators, etc., we are really moving ATM forward at a pace that is unprecedented. Previously in ATM we had lead times of 20 years before we could put something new in place. Today we have demonstrations of concepts for example that over a time period of less than 12 months have put totally new operations in place as it is so easy when you are following SWIM principles,” Paul Bosman, manager of the SWIM unit at Eurocontrol, told Avionics Magazine.

Among those recognized by this year’s SWIM Master Class was EU-METNET, a grouping of European national meteorological service providers that won the Best-in-Class award for the SWIM information services category with its 4D WeatherCube. The solution provides tailored meteorological information to ATM stakeholders translated into a user-specific data format via the SWIM-compliant "4D-WeatherCube portal."

According to Ruben Rohr, ATM information management expert at SESAR JU, the future possibilities for SWIM are bright as the industry with organizations such as EU-METNET and others that participated in the Master Class are just scratching the surface as to the solutions that can become available.

“Even though our primary focus is on flight dispatch and flight briefings, I think we are also looking into further integration of flight operations aspect into the ATM operations by feeding updated flight information into complexity management and arrival management,” Rohr told Avionics Magazine. “SWIM addresses all aspects, also dynamic updates of aeronautical and meteorological information will also link in the future to in-flight updates all the way into the cockpit.”
Contrail Service for Aviation
[ConSA]

Document Information

Company: AIRBUS Defence and Space and Luciad
Team Leader: Dirk Schindler and Robin Houtmeyers
Project name: Contrail Forecasting Web Service for Aviation (named ConSA – Contrail Service for Aviation)

Partners:

Summary

For the SWIM Master Class 2015, AIRBUS Defence and Space together with Luciad developed a SWIM-based contrail forecasting service enabled by the 4DWeatherCube (EUMETNET). Since contrail forming causes a net warming effect, the overall objective is to support ATM stakeholders in the effort to reduce the environmental impact of aviation. The service named “ConSA” (Contrail Service for Aviation) is in line with one of SESAR’s prime objectives “Reduction of environmental impact by 10% per flight”.

The service calculates probable forming of contrail objects on given weather conditions provided there are flights in those areas. Even small changes in the flight path can sometimes prevent contrail forming. It would be a high challenge for air traffic controllers or pilots to avoid or reduce forming of contrails for many flights without any technological assistance. With ConSA based on SWIM a comprehensive incentive for the ATM world is provided, allowing to consider the impact of contrail forming in flight planning and during execution.

ConSA has been designed as a very accurate, fast, user-friendly and flexible service. Being entirely based on SWIM-adopted standards such as OGC web services, NetCDF and WXXM, it seamlessly integrates within a SWIM environment.
Contrail Service for Aviation

What are Contrails?
Contrails are cloud-like trails formed behind an aircraft. They are formed when water vapor condenses and freezes around small particles (aerosols) that exist in aircraft exhaust. These trails can evaporate in minutes or persist for 24 hours and form cirrus clouds. Figure 1 shows the exhaust contrails and (b) cirrus clouds.

These clouds (also called cirrus clouds) are not distinguishable from normal cirrus clouds. The figure shows contrails and the resulting cirrus clouds.

Environmental Context
Contrails and resulting cirrus reflect incoming solar radiation (also called radiative forcing (RF)) and trap outgoing radiation emitted by the Earth, thereby affecting the Earth’s radiation balance. The Earth’s radiation balance accounts for how much energy comes into the Earth’s atmosphere, how much energy is lost to space and thus calculates the remainder of energy on Earth and its atmosphere. Research has found that the overall effect of contrail formation on Earth’s climate is negative, as it contributes to global warming.

Besides forming of contrails aviation causes further impact on Earth’s environment. The relation of the most relevant pollutants induced by aviation and their respective radiative forcing is shown in Figure 2. The image is referred from a research paper of Dr. Sausen et al. The effect of RF resulting from contrails is about 2/3 of the RF effect resulting from induced CO2. Strong effect derives from cirrus.

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Figure 2: Radiative Forcing (RF) caused by factors of aviation induced pollution

\[ \text{by Prof. Dr. Schumann from DLR (Deutsches Zentrum für Luft- und Raumfahrt)} \]
Relation to Aviation in the SES
Today an average of 30,000 flights crosses the Single European Sky every day. The tendency for the number of flights is still to increase over time. Hence it is obvious that the impact of aviation onto earth environment needs to be considered.
Aircraft engine emissions like smoke, nitrogen oxides and hydrocarbons are currently regulated (in airport zones) by the FAA and the ICAO. Carbon dioxide regulation is actually in process. Today there are no plans for a contrail regulation.
Hence the impact of contrails on Earth’s environment shall not be underestimated and the tendency of contrail related impact will increase with growing air traffic.

SWIM-enabled Solution
On basis of SWIM (System Wide Information Management) the necessary information and technology is available to introduce technical support into the matter of contrail forming prediction. To make it easy for operators (e.g. Flight Planners, Mission Planners, NM (Network Manager) Operators, Airspace Managers) data from 3 domains had to be combined in a user-friendly, comprehensive and performant way. The domains are: Meteorology, ATM and Mission/Flight Planning.

Building on the high performance engine from Luciad and big amounts of data from the 4DWeatherCube, flight plan data and En-Route mission planning can be processed and displayed nicely. The CAPS®ConSA® application provides functions for fast decision making regarding the probability of contrail forming from a single trajectory (see Figure 3 (a)) or within a defined volume of airspace (see Figure 3 (b)). The service calculates the probability for intense contrail forming on the basis of weather forecast data from the 4DWeatherCube.

Trade-Off
As the aviation industry is under high economic pressure aircraft operators need to act and plan very efficiently. Hence a trade-off between shortest flight path, optimum flight profile and least environmental impact needs to be found. CAPS®ConSA® assist in finding a solution which combines optimized (i.e. shortest or fastest) flight path with avoidance of contrail formation. Leading to a trajectory which will help to use minimized amount of fuel, produce less CO2 and at the same time reduce amount of contrail insertion into the atmosphere. Sometimes a good solution for all aspects can be found, which serves airspace users’ needs and environment simultaneously.

Figure 3: Optimizing 4D trajectory (a) and ARES (b) for contrail prediction

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* A combination of CAPS (Collaborative Airspace Provision Service) and ConSA provides optimum support for airspace users and other ATM operators.
Single European Sky Awards 2016
8th March 2016