



SESAR SOLUTIONS CATALOGUE **2021**



Fourth edition

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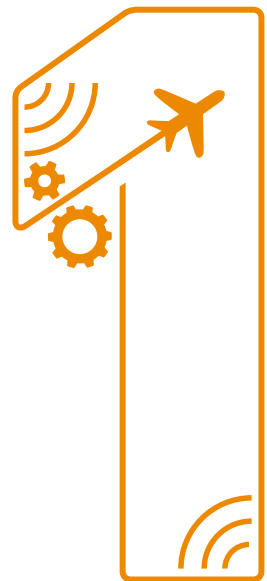
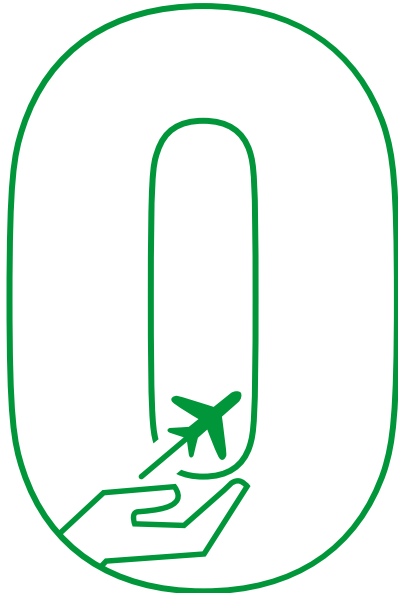
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Fourth edition

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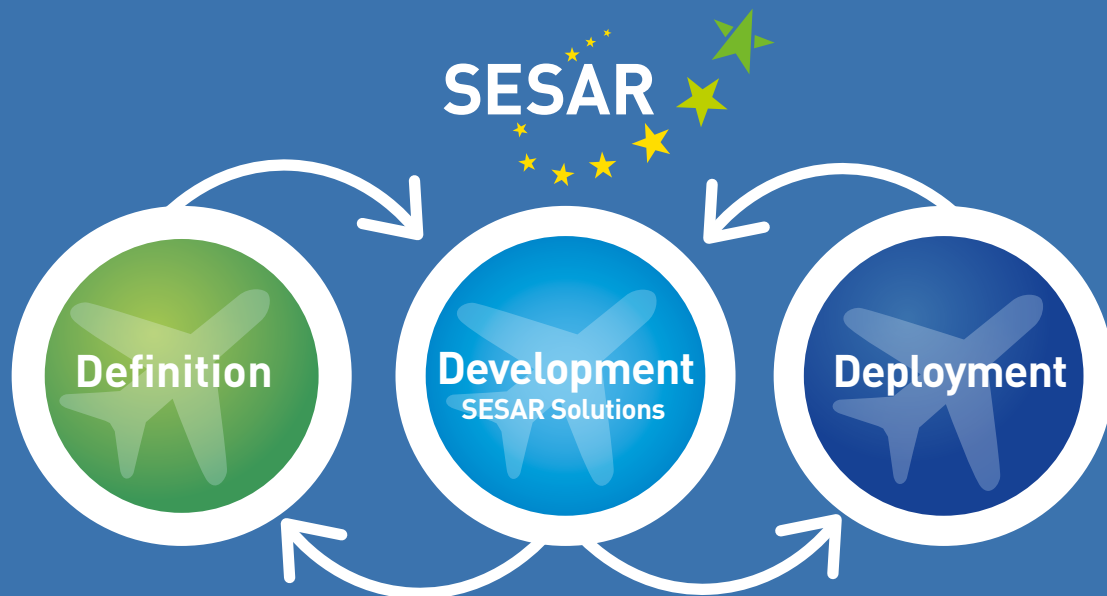
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About SESAR

SESAR is the technological pillar of the EU's Single European Sky policy and a key enabler of the European Commission's Sustainable and Smart Mobility Strategy. SESAR defines, develops and deploys technologies to transform air traffic management in Europe.

The SESAR Joint Undertaking (SESAR JU) is the public-private partnership set up to deliver technological solutions to make this transformation a reality. It works with all actors in the aviation value chain to agree on the research and development priorities, as well as technology roll-out plans, which are documented in the European ATM Master Plan - a collaboratively-agreed roadmap for ATM modernisation.

Founded by the European Union and EUROCONTROL, the SESAR JU has 19 members, who together with their partners and affiliate associations represent over 100 companies working in Europe and beyond. The SESAR JU also works closely with staff associations, regulators, airport operators, airspace users, the military and the scientific community.



European ATM Master Plan

- ▶ A roadmap for ATM modernisation
- ▶ Meeting the performance objectives of the Single European Sky
- ▶ Ensuring support with ICAO's global air navigation plan

- ▶ Exploring & developing operational & technology Solutions
- ▶ Validating & demonstrating Solutions in real-operational environments
- ▶ Delivering a catalogue of Solutions to transform ATM

- ▶ Implementation of SESAR Solutions to answer local needs
- ▶ Synchronised deployment to deliver Europe-wide benefits

Message from the SESAR JU founding members



Henrik Hololei,
Director-General for
Mobility and Transport
at the European
Commission, and
Chair of the SESAR JU
Administrative Board

Delivering scalable airspace capacity and avoiding congestion in the air and on the ground, as well as reducing the environmental impact are the biggest challenges facing European aviation today. They affect all of us – airspace users, national governments, economic operators and, of course, the travelling public. To address them, we must forge ahead with the drivers for sustainable growth outlined in the EU Aviation Strategy, such as creating a genuine Single European Sky, and pursuing the related innovation activities led by SESAR JU and its members.

The SESAR Solutions Catalogue is a very comprehensive overview of the status of Joint Undertaking's Research & Development activities, and shows that Europe is embracing innovation, digitalisation and automation to further increase safety, capacity and flight efficiency.

In doing so, we must continue to contribute to the sustainable growth of the aviation sector.

We would all like to see Europe leading globally in digital innovation, making a real difference and creating interoperable as well as cyber-secured systems. I am proud that SESAR, as illustrated in this catalogue, is keeping Europe at the cutting edge of technology, innovation and collaboration.



Eamonn Brennan,
Director General,
EUROCONTROL,
and Vice-Chairman
of the SESAR JU
Administrative Board

The COVID-19 crisis, with its devastating impact on aviation, has been a wake-up call for European ATM, highlighting even more the need for a new ATM infrastructure, a more digitalised, scalable, reactive and efficient system. It is encouraging to see the recovery is underway and stakeholders are sharing the same vision of building back better.

In the meantime, the environmental challenge has become critical, with the hugely ambitious objective to totally decarbonise aviation by 2050. Implementing the green trajectory is imperative as the current 10% flight inefficiencies in fuel burn and CO₂ emissions are no longer acceptable.

We must also factor in the arrival of new entrants, with new integration needs in the airspace: at low altitude with drones and urban Air Mobility, in controlled airspace with military RPAS, and at very high altitude with pseudo-satellites, balloons and stratospheric flights.

It is the role of the SESAR project, under the leadership of the European Commission, to propose a global European solution to all these challenges. This new version of the SESAR solutions catalogue is a key enabler as it makes available many key validated components to all European Aviation stakeholders.

As Network Manager, and a founding member of the SESAR JU, EUROCONTROL is proud to have contributed to the programme, with our specific focus on Pan-European network, master planning, defragmentation, interoperability, environment, performance and gate-to-gate operational approach.

Looking at the big picture, it is striking to see all SESAR building blocks already available: SWIM as a digital backbone, TBO and capacity on-demand as an operational concept, enhanced datalink clearances, advanced-FUA, datalink clearances, CDO/CCO, STAM, extended -AMAN/DMAN - and many more - as key enablers. Now our challenge is to move forward together and put them into operation.

Foreword



Richard Frizon,
Interim Executive Director,
SESAR Joint Undertaking

N*ecessity is the mother of invention.* That proverb rings true today, especially for Europe's aviation industry. The combination of the climate and COVID crises is accelerating a societal shift towards more sustainable air transport and renewing momentum among airports, airlines and air navigation service providers to rethink their business models and operations. The dual crisis also means that collaboration and the pooling of resources is more critical than ever, since industry-wide challenges can only be overcome together.

That's where SESAR innovation comes into play and the digital transformation of air traffic management. Through our partnership we are advancing technologies that will make the system more scalable and resilient to disruptions like the pandemic, as well as more fuel efficient and environmentally sustainable. Although developed prior to the pandemic, the solutions captured in this fourth edition of the SESAR Solutions Catalogue offer a pathway to recovery in the short term, while also laying the foundations for a more far-reaching transformation of ATM.

This latest edition covers the results of both the first R&D programme (SESAR 1) and the current programme (SESAR 2020); just over 100 solutions, a good portion of which are in the process of implementation at local and European levels. It also presents details of the ongoing R&D (candidate solutions) as we enter the final stretch of SESAR 2020, as well as what is on the horizon with our ongoing research and innovation projects.

This Catalogue is the result of strong collaboration between the public-private partners that make up the SESAR JU. Together we have created a SESAR innovation pipeline through which concepts are transformed into tangible solutions. The pipeline is composed of 67 research projects and demonstrators, more than 50 test sites and is staffed by 2,500 researchers, controllers, pilots and engineers from across Europe.

Not only do our members come together to pool their resources and expertise, they also make sure that research and innovation is carried out in a joined-up way so that the solutions when implemented together not only fulfil the Digital European Sky vision but support the EU in reaching the goals of the 'European Green Deal' and the 'Europe fit for the digital age' initiatives.

This Catalogue is a living document and will be updated as more solutions become ready for industrialisation and implementation.

Enjoy the read!

Through our partnership we are advancing technologies that will make the system more scalable and resilient to disruptions like the pandemic, as well as more fuel efficient and environmentally sustainable. Although developed prior to the pandemic, the solutions captured in this fourth edition of the SESAR Solutions Catalogue offer a pathway to recovery in the short term, while also laying the foundations for a more far-reaching transformation of ATM.

Introduction

Changing world, changing expectations

The aviation ecosystem is changing, starting with the aircraft itself. Soon, conventional aircraft will share the airspace with many other types of air vehicles from drones and air taxis to electric or supersonic aircraft, as well as those flying above commercial aircraft, such as balloons flying at higher altitude, those used for environmental surveillance, or for bringing high-speed internet access to remote areas. Aviation is also expected to become part of an intermodal transport network, offering passengers smart travel options and a seamless travel experience. All these changes make for a complex and dense airspace, one that cannot be managed or sustained using the labour-intensive procedures and systems that make up air traffic management today.

At the same time, the COVID-induced hiatus in air travel, which has put at risk an industry essential for Europe's economy and connectivity, has given renewed momentum to efforts to build a more resilient business model and streamlined infrastructure for aviation. The health crisis has also accelerated a change in attitude towards climate change and underlined the need to speed up efforts to make aviation more sustainable for the generations to come. Multiple technology pathways are required, one of which is the digital transformation of aviation's infrastructure (digital European sky), the benefits of which would already be felt in the short

term before the energy transition, with its sustainable aviation fuels and new propulsion systems, come into play.

Towards a digital European sky

The digital European sky was first proposed by the SESAR Joint Undertaking in 2017 ⁽¹⁾, and then further detailed in 2019 in a commonly agreed roadmap by stakeholders from across the aviation community ⁽²⁾. Further support for the digital European sky was provided by the Wise Person's Group, established by the European Commission to provide recommendations on the future of the Single European Sky ⁽³⁾, and a joint declaration by industry ⁽⁴⁾.

The digital European sky leverages the latest digital technologies ("SESAR Solutions") to transform Europe's aviation's infrastructure (air traffic management - ATM), enabling it to handle the future demand and diversity of air traffic safely and efficiently, while minimising its environmental impact. This transformation centres on technologies that can increase the levels of automation, cyber-secure data sharing and connectivity in air traffic management, as well as the virtualisation of its infrastructure and air traffic service provision in all types of airspace, including for very-low and high-altitude operations. In doing so, these technologies enable the system to become more scalable and agile, while building resilience to disruptions, changes in traffic demand and diversity of air vehicles. These attributes are all key to future proofing the system in a smart and sustainable way.

Supporting European strategic agenda

SESAR innovation and the vision of digital European sky matches the ambitions of several of the European Commission's top strategic priorities, including the Smart and Sustainability Strategy (including Drone 2.0 Strategy), the European Green Deal and a "Europe fit for the digital age" initiative, as well as the long term goals of the Single European Sky initiative.

1 Digitalising Europe's aviation infrastructure, October 2017

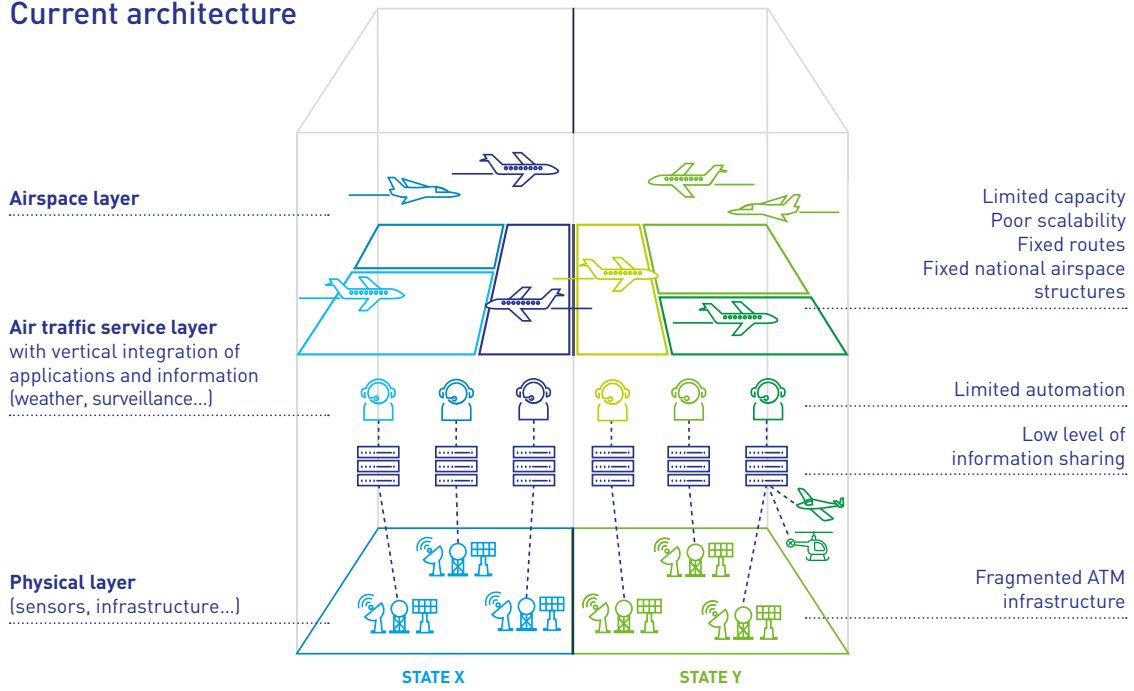
2 European ATM Master Plan, 4th edition, December 2019

3 A report of the Wise Person's Group, established by the European Commission to provide recommendations on the future of the Single European Sky, April 2019

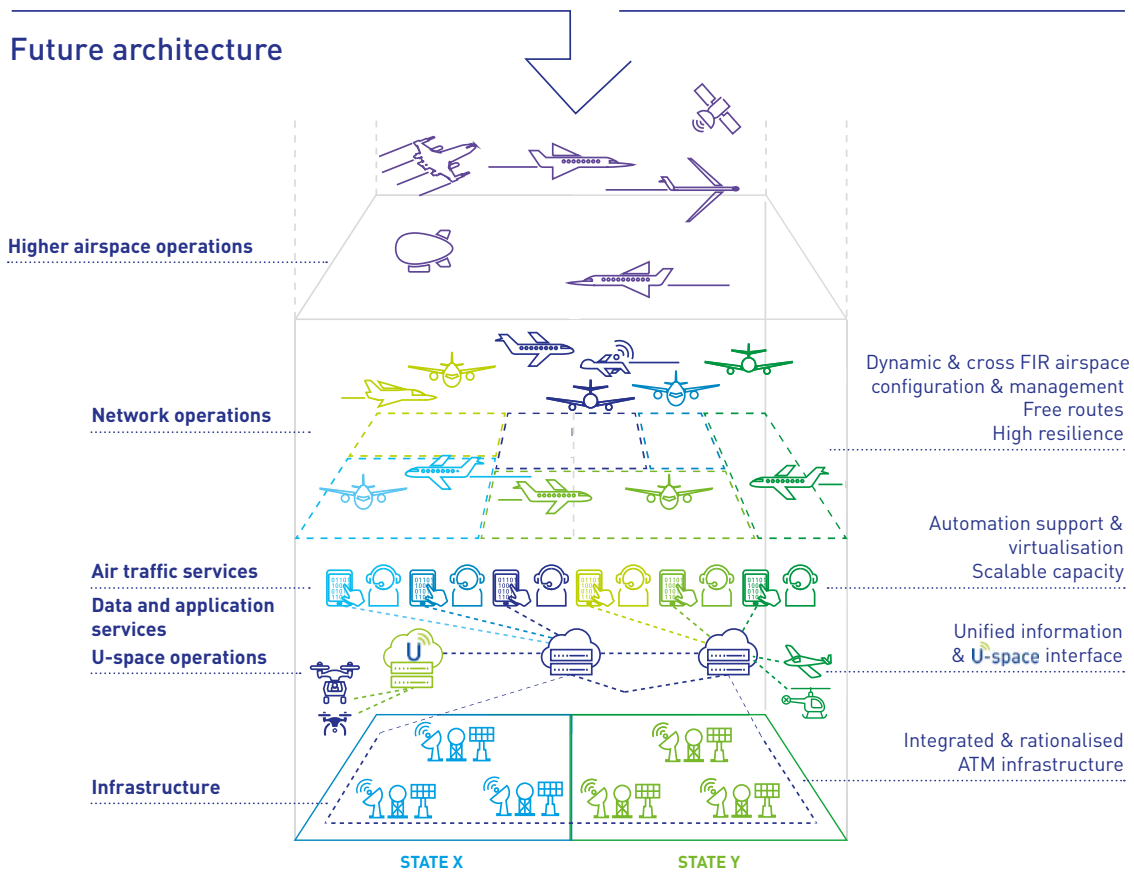
4 Joint Stakeholder Declaration for a Digital European Sky, September 2019

EVOLUTION OF THE EUROPEAN SKY

Current architecture



Future architecture



Source: Updated from ATM Master Plan 2020 edition

Cataloguing progress

The SESAR Solutions Catalogue charts progress in developing the technological and procedural solutions needed for delivering the digital European sky.

The publication contains 101 delivered solutions (reaching required level of maturity for industrialisation) addressing

key areas of the ATM value chain, notably airport operations, air traffic services, network operations and the enabling infrastructure. Over half of the delivered solutions are now part of deployment plans at local and European levels (See annex I for more details), proving tangible benefits in terms of cost efficiency, capacity, safety and the environment.

The Catalogue also presents details of the ongoing research and innovation on 80 candidate solutions in SESAR 2020, and progress towards the vision of the digital European sky. Finally, the publication gives a flavour of what's on the horizon thanks to promising innovations underway in all three strands of research (exploratory, industrial and demonstrations).

This Catalogue* is a living document and will be updated as more solutions become ready for industrialisation and deployment within the framework of SESAR research and innovation.

European ATM Master Plan

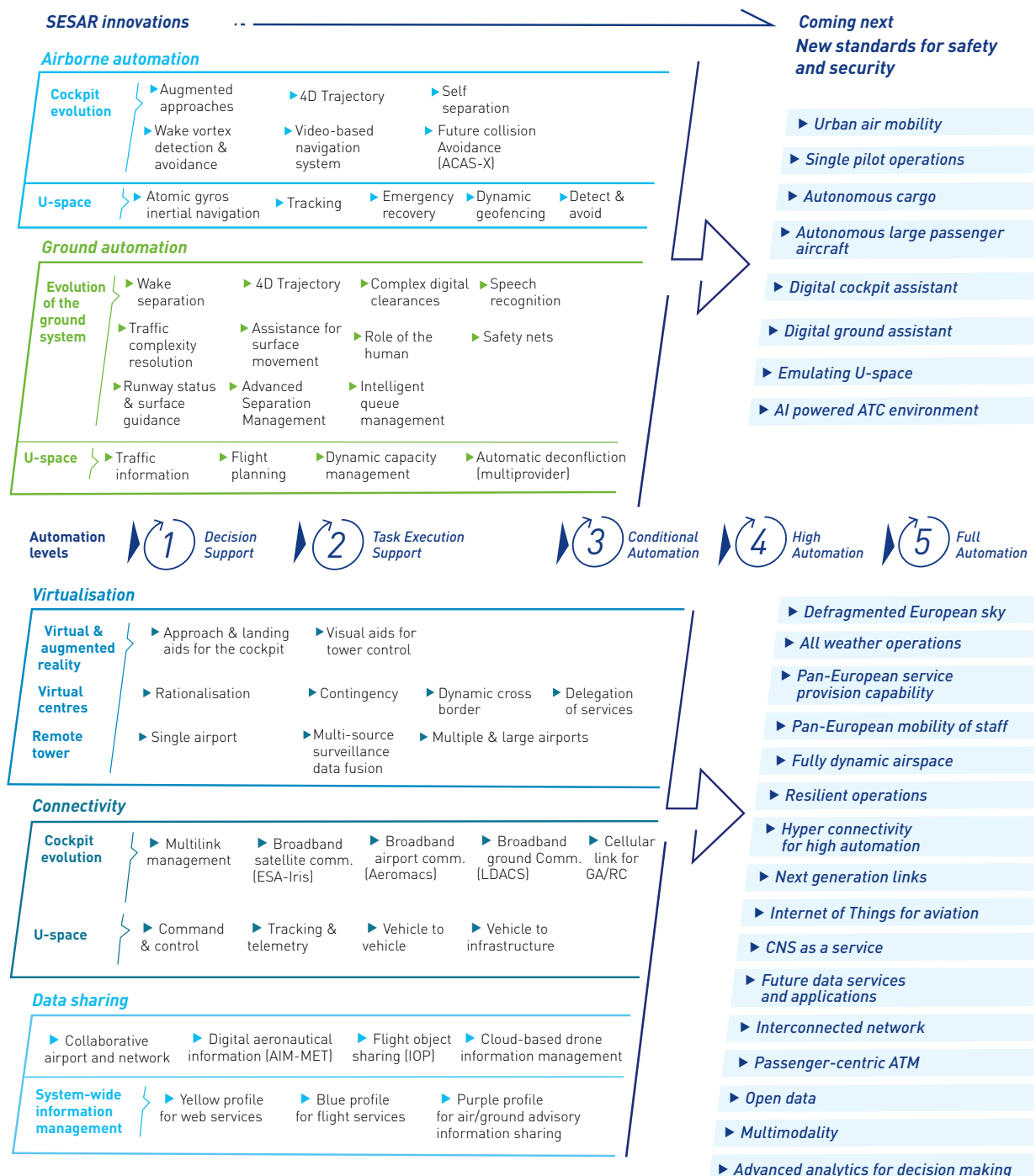
The vision for the digital European sky is captured within the European ATM Master Plan - a collaboratively agreed roadmap for ATM modernisation. The Master Plan is regularly updated to reflect the changing landscape in order to prioritise research and innovation activities and the solutions needed. It also sets out transversal activities to ensure that the resulting solutions are interoperable and bring expected performance.

What are SESAR Solutions?

SESAR Solutions refer to new or improved operational procedures or technologies that are designed to meet the essential operational improvements outlined in the European ATM Master Plan. They are also developed in full accordance with the International Civil Aviation Organization (ICAO) and the Global Air Navigation Plan (GANP) and therefore applicable to ATM environments worldwide. Each solution is accompanied by a set of documents to support its implementation, including operational services and environment descriptions, safety, performance and interoperability requirements, technical specifications, regulatory recommendations, safety and security assessments, human and environmental performance reports, relevant ICAO and industry standards needed for implementation.

* The current edition captures the status of solutions up to Release 9.

DISRUPTIVE AUTOMATION FOR THE DIGITAL EUROPEAN SKY



Source: ATM Master Plan 2020 edition

Spotlight on sustainability

The European Green Deal launched by the European Commission in December 2019 aims to create the world's first climate-neutral bloc by 2050. This ambitious target calls for deep-rooted change across the aviation sector and places significantly stronger focus on the environmental impact of flying. Multiple technology pathways are required, one of which is the digital transformation of air traffic management, where SESAR innovation comes into play. Over the past 10 years the SESAR JU has worked to improve the environmental footprint of air traffic management, from CO₂ and non-CO₂ emissions, to noise and local air quality.

Many of solutions delivered so far offer direct and indirect benefits for the environment, with more solutions in the pipeline in SESAR 2020. These include solutions such as wake turbulence separation (for arrivals and departure), optimised use of runway configuration for multiple runway airports, or even optimised

integration of arrival and departure traffic flows for single and multiple runway airports. Looking ahead, it is anticipated that the next generation of SESAR solutions will contribute to a reduction of some 450 kg CO₂ per flight.

Considering the urgency of the climate situation, the SESAR JU is looking at how to accelerate the digital transformation in order to support a swift transition to greener aviation. That will be the focus of the next wave of SESAR research and innovation and the SESAR 3 Joint Undertaking – a renewed and broader partnership aimed at delivering the Digital European Sky. Large-scale demonstrators will be part of this next phase and will be key to bridging the industrialisation gap, bringing these innovations to scale and encouraging rapid implementation by industry. These will focus on solutions enabling the “perfect flight” from an emissions perspective, eliminating unnecessary ATC interventions that would result in a degradation of the optimum trajectory and generate extra emissions.

SPOT THE SUSTAINABLE LABEL!

Watch out for this icon in the solution pages. It denotes the solutions that are offering benefits in terms of fuel efficiency and reducing aviation's climate impact.





Reader's guide to the Catalogue

OPERATIONAL AREAS

The Catalogue is structured according to the four operational areas targeted by the solutions.



High-performing airport operations, including total airport management, remote towers, runway throughput capabilities, navigation and routing tools, airport safety alerts for controller and pilots



Optimised network operations, including dynamic collaborative tools to manage ATC airspace configuration (sectors), and civil-military collaboration for greater predictability and management of operations and airspace use



Advanced air traffic services, including time-based separation and European wake vortex re-categorisation (RECAT-EU), better sequencing of traffic, automation support tools, integration of all vehicles



Enabling infrastructure, including CNS integration to facilitate economies of scale and seamless service delivery; and system-wide information management governance, architecture and technology solutions and services for information exchange

MATURITY

Solutions are also presented according to their **level of maturity**.

SECTION I - DELIVERED: features 101 solutions, which reached maturity during the first R&D programme, which ran from 2008 to 2016 (SESAR 1), and SESAR 2020 (Wave 1) which ran from 2017 to 2019). A number of these are mandated for synchronised deployment ¹, which requires ANSPs and airspace users to roll out the solutions in a timely and coordinated way. At the same time, local implementation have also started.

SECTION II - IN THE PIPELINE: features 80 candidate solutions for which research and development is ongoing in the programme (Wave 2 and 3).





See annex III for details of the projects that are advancing these solutions.

SECTION III - ON THE HORIZON: provides a full overview of the current projects in all three strands of research (exploratory, industrial and demonstrations), offering a flavour of what's in the innovation pipeline.

¹ See Annex I for an overview of implementation

STAKEHOLDERS

SESAR Solutions meet the business needs of a range of ATM stakeholders. For each solution, the targeted stakeholders are indicated using these icons.

 ANSP	airspace navigation service providers (civil and military)
 AO	airport operators (civil and military)
 AU	Airspace users (civil and military)
 NM	Network Manager

BENEFITS

SESAR Solutions are assessed according to a set of key performance/benefit indicators. For each solution, the relevant performance areas are indicated.



Improved predictability: measured by the variability in the duration of the flight;



Reduced costs: refers to the costs associated with air navigation service provision;



Increased airport capacity: refers to runway throughput at 'best-in-class' airports which already operate close to their capacity limit;



Increased en-route airspace capacity: refers to en-route airspace, which is close to saturation



Increased TMA airspace capacity: refers to airspace in the surrounding area of one or more airports (terminal manoeuvring area)



Reduced fuel consumption and emissions: refers to the average reduction in fuel consumption per flight in Europe (at the level of European Civil Aviation Conference).



Maintained or enhanced safety: ensuring gate-to-gate traffic safety (in flight as well as during surface movement, i.e. taxi and on the runway)).

IMPLEMENTATION

Work is underway to industrialise and subsequently implement many of the delivered solutions in the catalogue (Section I), either at local level or in a synchronised way across Europe². This status of implementation is indicated for delivered solutions, where relevant.



Denotes Europe-wide synchronised deployment



Denotes local implementations according to specific business needs

² See Annex I for an overview of implementation



Delivered solutions

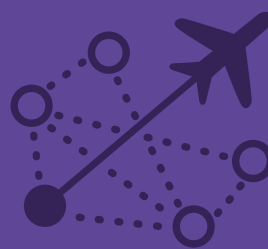
This section features 101 solutions, which reached maturity during the first R&D programme, which ran from 2008 to 2016 (SESAR 1), and SESAR 2020 (Wave 1) which ran from 2017 to 2019). A number of these are mandated for synchronised deployment in, which requires ANSPs and airspace users to roll out the solutions in a timely and coordinated way. At the same time, local implementation has also started.



**High performing
airport operations**



**Advanced air traffic
services**



**Optimised network
operations**



**Enabling aviation
infrastructure**

High-performing airport operations

The future European ATM system relies on the full integration of airports as nodes into the network. This implies enhanced airport operations, ensuring a seamless process through collaborative decision making (CDM), in both normal and adverse conditions. This feature addresses the enhancement of runway throughput, integrated surface management, airport safety nets and total airport management.

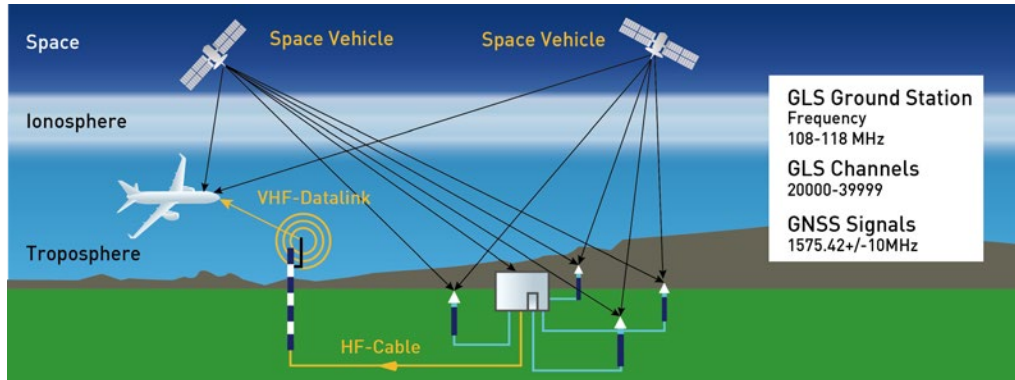




SATELLITES DELIVER PRECISION LANDING GUIDANCE

SJU references:
#55/Release 4

Precision approaches using GBAS Category II/III



STAKEHOLDERS
ANSP
AO
AU
NM

For more than 50 years airports have relied on instrument landing systems (ILS) to provide pilots with approach and landing guidance in low-visibility conditions, such as heavy rain and low cloud. Although the system has proved to be reliable and functional, ILS is costly to maintain and has operational limitations that reduce runway capacity in certain conditions. It is no surprise then that airports are turning to other solutions, such as ground-based augmentation of satellite navigation systems (GBAS), to meet their capacity needs and reduce delays and disruptions for airspace users and passengers.

GBAS uses four global navigation satellite system (GNSS) reference receivers and a VHF broadcast transmitter system. Its ground system measures distances to GNSS satellites (e.g. Galileo), and computes error corrections and integrity data based on signal quality and known fixed positions of the GNSS reference receivers. Together with the approach path and quality information the corrections are broadcast as digital-coded data to all GNSS landing system (GLS)-equipped aircraft within range. The aircraft receives this information, calculates the (differentially) corrected position and deviations from the selected approach path, allowing it to land automatically in low-visibility conditions.

GBAS CAT II/III can enable precision landing in low-visibility conditions, helping to maintain safety and capacity performance. SESAR validations have shown that the GBAS CAT II/III can overcome challenges posed by low-visibility conditions, reducing runway blocking times and thereby increasing arrival capacity (by between two and six aircraft per hour) compared to ILS.

GBAS requires lower installation and maintenance costs compared to conventional instrument landing systems (ILS)

This solution is linked to ICAO's Annex 10 on Gost D standard and EUROCAE's ED-88-114

BENEFITS

- Improved resilience by limiting the capacity reduction in degraded situations and by avoiding critical and sensitive areas)
- Reduced installation and maintenance costs compared to ILS
- Maintained level of safety
- Greater frequency efficiency
- Improved environmental impact due to shorter routes and noise abatement



SJU references:
#117/Release 7,
See PJ.03a.04

ENABLING ACCESS TO AIRPORTS IN LOW-VISIBILITY CONDITIONS

Reducing landing minima in low-visibility conditions using EFVS to land

STAKEHOLDERS

ANSP

AO

AU

NM



BENEFITS

- Improved access to secondary airports
- Operational and cost efficiency

With the main airport hubs becoming busier, secondary gateways will come to the fore, dealing not only in an increasing number of scheduled flights but also acting as an important alternative for diverted flights. It is therefore crucial that accessibility to those airports in degraded weather conditions is enhanced. However, these airports have limited resources to invest in advanced ground infrastructure.

One option is to take advantage of enhanced flight vision systems (EFVS) that are located on board the aircraft and can be used by all aircraft types. Delivered by SESAR in 2018, the system can be displayed to the pilot using a heads-up display (HUD) or equivalent display such as coloured helmet-mounted display, and advanced vision sensors. These technologies provide the required enhanced flight visibility in certain visibility-limiting conditions.

These features make the solution a useful capability for airspace users in the business aviation regional and even commercial airspace users, to access to secondary non CATII/III airport, fitted with performance-based navigation (PBN) or ILS instrument approach procedures. This solution allows secondary airports operators with limited resources to reduce landing minima with no additional infrastructure and maintenance cost, provided the aerodrome has been declared suitable for EFVS operations.

With a view to the large-scale implementation of EFVS across Europe, the SESAR AAL2 very large-scale demo project AAL-Augmented Approach to Land 2 - successfully demonstrated EFVS operations in a fully operational context and in poor visibility conditions. The solution is implemented in Sweden and France.



SYNTHETIC VISION PROVIDES APPROACH AND TAXI GUIDANCE TO PILOTS

Enhanced visual operations

SJU references:
#PJ.03a-04/
Release 9



Medium and small airfields have limited resources to invest in advanced ground infrastructure to support all weather operations. Vision-based technologies offer an alternative located on board the aircraft and available to all aircraft types.

This solution refers to enhanced vision systems (EVS) and synthetic vision systems (SVS), alone or in combination, which enable more efficient taxi, and landing operations in low-visibility conditions (LVC). The operational credits provided for landing are beneficial to medium and small aerodromes using category I and required navigation (RNAV) approach procedures while the vision based system use on the surface benefits larger aerodromes with busy or complex taxi operations. The on-board vision systems receive information from infrared and multispectral sensors.

SESAR tested head-mounted displays (HMDs) fitted with surface routing, live traffic and clearance information in various weather conditions. In addition to fast-time simulations at Czech Republic, live flight trials were conducted in Italy and France.

In the case of landing operations in low visibility conditions, a head-mounted display provides an acceptable alternative to a head-up display (HUD) and also provided taxi-in support.

In the case of taxi operations, HMD was shown to be feasible. The workshare between the pilot flying and the pilot monitoring was unchanged compared to current operations and the display of taxi guidance information was shown to be extremely valuable in large airport environments. Flight crew liked the three-dimensional depiction of surrounding traffic.

When EVS and SVS are used together to deliver combined vision system (CVS) the solution helps to interpret the environment, especially if infrared camera performance is insufficient, and secondary airports in particular stand to benefit as a result of fewer cancellations, diversions and delays.

Results submitted to EASA rulemaking for improving AWO/EFVS regulation considerations.

The solution is available for industrialisation.

STAKEHOLDERS

ANSP

AO

AU

NM

BENEFITS

- Improved airport resilience in poor weather
- Better situational awareness for flight crew
- Enhanced capacity in low visibility conditions

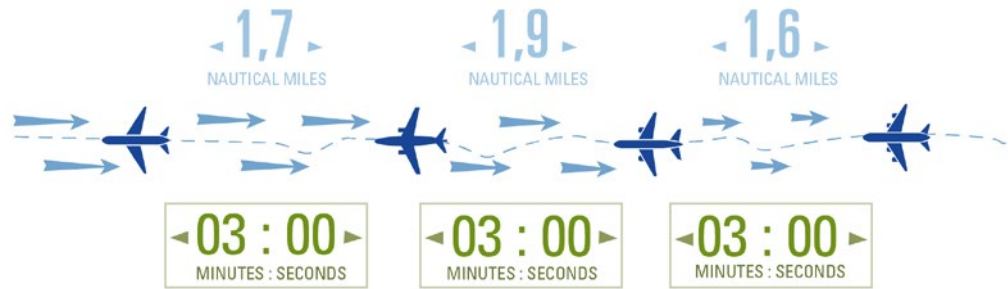


SJU references:
#64/Release 2

CAPACITY GAINS WITH TIME-BASED ARRIVALS

Time-based separation

STAKEHOLDERS
ANSP
AO
AU
NM



BENEFITS

- Improved airport capacity as a result of increased aircraft landing rates in strong headwind conditions
- Reduction in holding times as well as stack entry to touchdown times
- Increased situational awareness

Today, aircraft making their final approach to land are obliged to maintain minimum separation distances. These distances are fixed whatever the wind conditions. When keeping to these distances in strong headwinds longer gaps of time develop between aircraft. This means fewer flights landing per hour (reduced airport capacity), leading to delays and increased holding at busy times, which results in increased fuel burn.

SESAR's time-based separation (TBS) replaces current distance separations with time intervals in order to adapt to weather conditions. It provides consistent time-based spacing between arriving aircraft in order to maintain runway approach capacity.

The TBS software uses real-time information about the weather, airspeed, ground speed, heading and altitude to display time-based separation and arrival speed information to the approach controller. No changes are required on board the aircraft, but the controller uses the real-time separation indicators to manage the final approach separations.

TBS research included analysis of the arrival paths of over 100,000 aircraft using state-of-the-art equipment to measure the behaviour of aircraft wake vortices. The procedure now is in daily use at London Heathrow, where, in strong wind conditions, it delivers up to 4.2 additional aircraft landings with TBS per hour compared to traditional distance-based separation procedures. TBS results in savings of 90k minutes of arrival delays, 15kt of fuel and 47kt of CO2 per annum.

The SESAR Solution is available for industrialisation. TBS entered into full-time service at London-Heathrow in March 2015.

Analysis has shown that there has been no increased risk to wake turbulence encounters, and no increase in the number of go-arounds following introduction of time-based separation at London Heathrow

This solution is linked to Eurocontrol's TBS specifications (STD-065)



SEPARATION DELIVERY TOOL INCREASES CAPACITY IN THE ARRIVAL STREAM

Optimised runway delivery on final approach

SJU references:
#PJ.02-01-01/
Release 9



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

Although low now, the forecast is that traffic will grow again which will pose a challenge for many of Europe’s busiest airports, especially during peak hours when demand cannot always be accommodated without inducing delay or increasing flying time. Europe’s wake vortex re-categorisation (RECAT-EU) scheme is helping to raise capacity by augmenting the ICAO wake classification with more categories, and already enables up to 8% more arrivals at airports, such as Paris CDG, Leipzig-Halle, London Heathrow and Vienna. SESAR tools are now available to help manage the required separation or space between arrival pairs on final approach to the runway. The optimised runway delivery (ORD) tool uses the distance-based and time-based wake separation rules, including the ICAO, RECAT-EU (see solution PJ.02-01-06), pairwise separation for arrivals (PWS-A)(see solution PJ.02-01-04) and weather dependent separation for arrivals (WDS-A) (see solution PJ.02-01-05) wake separation schemes, to consistently manage the spacing compression that occurs on short final from the lead aircraft crossing the deceleration fix.

BENEFITS

- Increased runway capacity and improved predictability
- Improved resilience during weather disturbances
- Decreased fuel burn from aircraft holding

SESAR JU partners completed seven exercises with both real-time and fast-time simulation activities at capacity-constrained airports in France, Denmark, Spain and Austria to validate the use of the ORD tool combined with various wake turbulence separation techniques. The activity assessed different arrival procedures including weather-dependent separations, static pairwise separations and ICAO time-based separations (TBS) using various runway configurations. The results show the ORD tool is operationally feasible and acceptable in both segregated and mixed mode runway operations in highly complex, large airport environments in low wind and strong wind conditions. Furthermore, it was shown that the tool could be combined with performance-based navigation (PBN) procedures with no negative impact on controllers’ work.

The solution is ready for industrialisation and has been implemented in the UK. It can be integrated into the controller working position and existing TBS system (if present), and uses weather services to measure or forecast wind on the final approach path. In addition to increased capacity, the solution improves predictability and resilience while reducing fuel burn from aircraft holding.

Validation exercises at capacity-constrained airports show this solution is ready for deployment at both segregated and mixed mode runway operations



SJU references:
#PJ.02-01-02/
Release 9

IMPROVED DEPARTURE TIMING CONTRIBUTES TO MORE PREDICTABLE, SAFER OPERATIONS AT BUSY AIRPORTS

Optimised spacing delivery for departure

STAKEHOLDERS

ANSP

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AU

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BENEFITS

- Increased runway capacity and improved predictability
- Reduced fuel burn from taxi-out time

Increasing existing runway capacity is an alternative to laying more concrete to accommodate traffic rising demand. Building on work completed by SESAR 1 on pairwise separation for departure, SESAR 2020 has further optimised wake turbulence separation categories to support safe, consistent and efficient departures, and deliver more predictable operations at Europe's busiest airports. The solution targets capacity constrained runways during high intensity runway operations by introducing an optimised spacing delivery (OSD) tool and its associated procedures to support safe and reliable handling of aircraft departures in accordance with ICAO wake separation rules. Variants of the tool support time-based separations or distance-based separations and spacing such as RECAT-EU (see solution PJ.02-01-06), pairwise separation for departures (PWS-D) (see solution PJ.02-01-06), weather dependent separation for departures (see solution PJ.02-01-03), with airports able to select a combined TBS/DBS variant where required.

SESAR partners demonstrated the solution at large and very large airports including Barcelona, Copenhagen, London-Heathrow, and Vienna where movements range from 260,000 to approximately 475,000 per year. Five real-time simulations were carried out to validate a range of departure operations including pairwise separations, weather-dependent separations and integration with an OSD tool.

The results show that the OSD tool is operationally feasible and acceptable. The tool aided the controllers by providing current wake separations and reducing their workload. This provided them with additional thinking time to perform other tasks. The solution is fully mature and ready for industrialisation and deployment. The OSD tool requires no change to modern aircraft systems but needs to be integrated into the controller working position and current TBS system (if present).

As a result of optimised spacing, aircraft departures are more consistent and there is less variability between planned and actual departure time. Fuel burn is reduced due to improved management of taxi-out time and runway capacity is increased.

The SESAR solution is operationally feasible and acceptable

The solution is available for industrialisation.



PREDICTABLE AIRCRAFT DEPARTURES IN ALL WEATHER IMPROVES AIRPORT SAFETY AND CAPACITY

SJU references:
#PJ.02-01-03/
Release 9

Weather-dependent reductions of wake turbulence separations for departures



STAKEHOLDERS

ANSP

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AU

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BENEFITS

- Additional resilience to weather and wind conditions
- Decrease in fuel burn from taxi-out time
- Less variability between planned and actual departure time
- Increased runway throughput

Maintaining runway throughput at Europe’s busiest airports regardless of the weather has a direct impact on the performance of the whole European network. SESAR partners started developing a wake separation scheme based on the crosswind concept in SESAR 1. SESAR 2020 subsequently validated the weather-dependent reductions of wake turbulence separations for departures (WDS-D) solution integrated in a departure optimised separation delivery (OSD) tool (PJ.02-01-02) in a real time simulation exercise at London-Heathrow. The solution is applicable to large and very large airports primarily and possibly regional airports, typically handling between 40,000 and 250,000 movements annually and operating close to their maximum capacity.

The results show that WDS-D is operationally feasible and acceptable. The tools enabled controllers to provide more granular and reduced weather-dependent wake separations to straight-out departures. Importantly, the research showed that strength of crosswind will affect exactly when a follower aircraft is clear of encountering the wake generated by the lead aircraft after the first turn, and this may change according to local aerodrome wind conditions.

The solution relies on meteorological services to measure and forecast crosswind and requires an enhanced OSD tool to be integrated into the controller working position and time-based separation system (if present).

The validation exercise provides the basis for an initial safety case proposal and makes clear the need for local investigative analysis before a general set of rules can be developed for approval by the European Aviation Safety Agency (EASA). However once mature, rules could be applied for reduced departure separations, along with procedures for tool failure scenarios and criteria required to activate or suspend weather-dependent separation for departures. There is also interest in a sequence optimisation tool to achieve the optimal departure sequence as a result of more granular wake separations.

Controllers provide more granular and reduced weather-dependent wake separations taking account of local variations



SJU references:
#PJ.02-01-04/
Release 9

CONTROLLER TOOLS OPTIMISE PAIRWISE ARRIVALS BASED ON TIME AND DISTANCE

Wake turbulence separations (for arrivals) based on static aircraft characteristics

STAKEHOLDERS

ANSP

AO

AU

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BENEFITS

- **Additional resilience to weather and wind conditions**
- **Decrease in fuel burn from taxi-out time**
- **Less variability between planned and actual departure time**
- **Increased runway throughput**

Aircraft traditionally apply safe separation rules based on aircraft size and the distance between the leader and its follower in order to avoid wake turbulence on final approach. More flexible time-based separation (TBS) criteria developed under SESAR 1 already allow more arrivals based on weather conditions and wind strength and SESAR 2020 is building on this work to further raise capacity. By maintaining throughput rates at Europe's busiest airports performance of the whole network stands to benefit.

This solution applies to pairwise separation for arrivals (PWS-A) rules for final approach consisting of both the 96 x 96 aircraft type based wake separation minima (for the most common aircraft in ECAC area) and the twenty wake category (20-CAT) based wake separation minima for arrival pairs involving all the remaining aircraft types. SESAR carried out five validation exercises in combination with the optimised runway delivery (ORD) tool (see solution PJ.02-01-01) using real-time and fast-time simulation techniques to assess the benefits and operational feasibility of these procedures.

EASA is reviewing a proposed amendment to the existing requirements for time-based and distance-based pairwise separations for arrivals under Reg. EC 2017/373 Annex IV Part-ATS

The findings show that use of PWS-A with the ORD tool in both segregated and mixed mode operations is operationally feasible and acceptable to controllers in a high complexity approach situation and a large airport environment. The simulations showed significant benefits for this operational improvement including increased resilience to disruption, less fuel burn from reduced flying time/holding, improved predictability and capacity.

The solution has no impact on aircraft systems but requires the ORD tool to be integrated into the controller working position and TBS (if present) along with provision of meteorological services to measure and forecast wind on final approach.

A regulatory change has been submitted to the European Aviation Safety Agency (EASA) for distance-based pairwise separation for arrivals, and is expected to become an amendment to the existing requirement ATS.TR.220 which applies to wake turbulence separation under Reg. EC 2017/373 Annex IV Part-ATS.

A separate regulatory change has been submitted to EASA relating to time-based pairwise separations for arrivals which is also likely to result in a change in requirement under the same EC wake turbulence separation regulation.



PRECISE WIND DATA SUPPORTS REDUCED SEPARATIONS BETWEEN AIRCRAFT ON FINAL APPROACH

SJU references:
#PJ.02-01-05/
Release 9

Weather-dependent reductions of wake turbulence separations for final approach



STAKEHOLDERS

ANSP

AO

AU

NM

Rules governing separation distances ensure aircraft avoid being disrupted by wake turbulence created by preceding aircraft on final approach. SESAR 1 has already demonstrated further optimisation of pairwise separation rules with the introduction of time-based separations (TBS) and this research is expanded under SESAR 2020 to increase capacity for high intensity runway operations in crosswinds.

BENEFITS

- Additional resilience to weather and wind conditions
- Decrease in fuel burn from taxi-out time
- Less variability between planned and actual departure time
- Increased runway throughput

Weather-dependent separations for arrivals (WDS-A) is the conditional reduction or suspension of wake separation minima on final approach, applicable under pre-defined wind conditions, so as to enable an increase in runway throughput compared to the applicable standard weather independent wake separation minima. Under pre-defined wind conditions, the wake turbulence generated by the lead aircraft is either wind transported out of the path of the follower aircraft on final approach or has decayed sufficiently to be acceptable to be encountered by the follower aircraft.

SESAR partners have developed a methodology for deriving a wake separation scheme based on crosswind conditions. The proposed WDS-A wake separation scheme has been tested in three validation exercises in combination with an optimised separation delivery (OSD) tool (see solution PJ.02-01-02) using both real-time and fast-time simulation activities in environments such as Paris Charles de Gaulle, Barcelona and Vienna airports. The use of the OSD tool improves the accuracy of separation delivery and reduces the number of unmanaged under-separations.

The solution is operationally feasible, enabling controllers to increase the accuracy of separation delivery and reduce the number of unmanaged under-separations

Results showed WDS-A is operationally feasible and acceptable in complex airport environments. Changing from time-based WDS to distance-based separations was also acceptable to controllers except during peak traffic periods. The exercises showed the operational improvement is beneficial when the crosswind on the ground is 10 knots or above for a continuous period.

The concept is mature and ready to be used with the addition of local seasonal weather analysis to support deployment. A reduction in separation minima requires development of a safety case.



SJU references:
#PJ.02-01-06/
Release 9

REDUCING DEPARTURE SEPARATIONS BASED ON AIRCRAFT CHARACTERISTICS

Wake turbulence separations (for departures) based on static aircraft characteristics

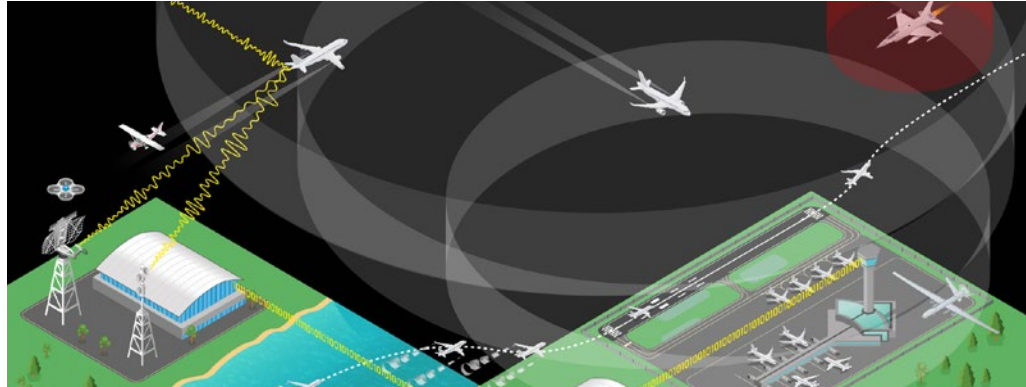
STAKEHOLDERS

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BENEFITS

- **Additional resilience to weather and wind conditions**
- **Decrease in fuel burn from taxi-out time**
- **Less variability between planned and actual departure time**
- **Increased runway throughput**

Runway capacity is a limiting factor at many of Europe's busiest airports, however new runway construction is unpopular and requires many years of planning to bring into operation. SESAR research is addressing alternative operational and technical improvements to increase traffic throughput while preserving safety and minimising the impact on the environment.

Europe's wake vortex re-categorisation (RECAT-EU) scheme is the basis of further research by SESAR partners into wake turbulence separation rules and ways of raising capacity for high intensity runway operations. In a series of real-time simulations, SESAR 2020 partners tested time-based separation procedures for different categories of aircraft used in combination with the optimised separation delivery (OSD) tool for controllers (see solution PJ.02-01-02). The simulations focused on large and very airports but benefits may be expected at medium airports depending on the local environment and constraints. The validation exercises reviewed time-based pairwise wake separation for different categories of aircraft and tested pairwise separation for departures (PWS-D).

The solution optimises wake separations between departures on the initial departure path by moving from a small number of wake categories (four to seven) to a scheme defined between aircraft type pairs for the 96 most common aircraft types operating at European airports, together with a scheme defined by a larger number of wake categories (20-CAT) for other aircraft type combinations.

The time-based pairwise wake separation scheme (7 -CAT matrix) developed in the RECAT-PWS-EU Safety Case Ed. 1.4 has been submitted to EASA

The results show that PWS-D used in combination with OSD is operationally feasible and acceptable for segregated runway operations. The solution is ready to be submitted to EASA once the safety case and supporting evidence has been assembled. Before PWS-D can be deployed, the OSD tool needs to be integrated with the controller working position and current time-based separation system (if present) with the addition of meteorological services to measure and forecast the wind on the final approach path.

The time-based PWS-D 7 category scheme is expected to become an EASA acceptable means of compliance for the requirement ATS.TR.220 Application of wake turbulence separation from Regulation EC 2017/373 Annex IV Part-ATS. Meanwhile, the development of the time-based 96x96 and 20-CAT wake separation rules should be assessed with the supporting safety case and evidence for submission to EASA for regulatory approval. This work is ongoing within the programme in PJ.02-W2 and as part of the very large-scale demonstration, SORT (see section III for information about these projects).



GROUND-BASED MEASURES REDUCE RISK OF WAKE TURBULENCE

Wake decay enhancing devices

SJU references:
#PJ.02-01-07/
Release 9



STAKEHOLDERS

ANSP

AO

AU

NM

Rules governing minimum separation standards between different aircraft types protect against wake turbulence affecting aircraft on arrival or departure. Large airports, where keeping the wake separation to a minimum to optimise runway throughput, can increase safety by installing wake vortex decay enhancing devices, co-called plate lines, which reduce the risk of low-altitude wake encounters.

SESAR 1 demonstrated that plate lines reduce the lifetime of long-lived wake vortices in proximity to the ground by about 20%, making wake encounters less likely. Further SESAR 2020 research and measurement conducted at Vienna Airport reveals accelerated average reduction of wake vortex lifetime of over 30%.

Wake vortex decay enhancing devices can be installed at any major European airport in order to increase safety by reducing the number of encounters. Each plate line consists of several upright plates that are installed beyond the ends of runways underneath the approach glide path where the individual plates are oriented in parallel to the runway centreline. While descending, wake vortices interact with the plates to generate disturbances that propagate in and against flight direction. These disturbances reduce the lifetime of the long-lived and potentially most hazardous wake vortices.

The wake decay enhancing method is passive, low-cost, robust, and safe. The installation of the plates increases flight safety and reduces the number of go-arounds. Approval of a permanent plate design by authorities will enable the concept to be installed with relatively little effort at multiple airports.

An EASA safety assessment found the plate lines comply with the relevant standards and regulations. Plate Lines are classified as an air traffic control system

The objective of the next phase is to industrialise the plate line concept into a prototype for a very large-scale demonstration ready for permanent installation at airports – This has been done as part of the SESAR SORT demo (see section III for more details of the project). This will allow analysis of aspects including the effects of individual aircraft types, flight altitudes, environmental conditions, the number of required plate lines and their location.

BENEFITS

- **Enhanced safety due to fewer wake encounters**
- **Fewer go-arounds**



SJU references:
#PJ.02-03/Release
9

HIGH ACCURACY SURVEILLANCE FREES UP CAPACITY ON APPROACH

Minimum pair separations based on required surveillance performance (RSP)

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BENEFITS

- Capacity increase as a result of reduced separation minima
- Additional resilience during peak traffic periods
- More efficient runway operations

Airport arrivals and departures are among the most safety-critical phases of flight. They also provide an opportunity to raise capacity by reducing the minimum separation distance between aircraft provided required surveillance performance (RSP) is in place. Minimum separation or spacing requirements between two aircraft on final approach to the same runway also takes into account runway occupancy time and wake separation constraints.

SESAR has demonstrated that a minimum radar separation of 2 nautical miles (NM) on final approach is feasible (compared with 2.5 NM or 3 NM standard operations) through a series of fast-time and real-time simulations. The activity was complemented by additional safety and human performance assessment studies, along with performance assessment of surveillance services and a collision risk modelling study specifically for 2NM a minimum radar separation.

The reduction of the in-trail minimum radar separation from 2.5 NM to 2 NM on final approach was found to be operationally feasible with no negative impact on safety or human performance. The benefits in terms of runway throughput, rate of go-arounds and fuel efficiency are dependent on the wind conditions and separation scheme applied.

EUROCONTROL ESASSP standard and EUROCAE WG102 standardisations documents need to be updated to take into account the 2 NM separation.

When combined with the SESAR optimised runway delivery (ORD) tool (see solution PJ.02-01-01), controllers can assess all applicable constraints including wake separation minimum, runway occupancy time constraints, and minimum radar separation to estimate a final target distance and mitigate against separation infringements. The validation activities for the operational use of the 2 NM minimum radar separation addressed both with-ORD and without-ORD cases. However, the cost benefit analysis and performance assessments focused on the 'with-ORD' case only.

The solution targets very large, large and medium airports that are capacity constrained during peak hours and where the runway throughput is impacted by moderate, strong and very strong wind conditions on the straight-in approach track resulting in the build-up of arrival delays and the potential need for flight cancellations. It requires approval by the local safety regulator to take account of local ATC approach procedures and associated tool support.

The solution is available for industrialisation.



BIG DATA ANALYTICS HELP TO REDUCE SEPARATION ON FINAL APPROACH

SJU references:
#PJ.02-08-03/
Release 9

Reduced separation based on local runway occupancy time characterisation



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Optimising runway capacity at Europe's largest airports will help to accommodate traffic demand and reduce the need to build new infrastructure at already busy airports. One way of optimising runway throughput is by reducing separation between aircraft, using better predicted runway occupancy times.

BENEFITS

- **Raises capacity by reducing in-trail separation**
- **Improves predictability and safety**
- **Improved productivity**

Runway occupancy times is one most constraining factors to reducing separation, alongside wake turbulence. The solution proposes to enhance runway throughput by enabling minimum distance-based surveillance separation reduction between some aircraft, based on the runway occupancy time (ROT) characterisation of the leader aircraft. The operational application can be either based per aircraft type or per aircraft ROT-based category.

The solution can increase runway throughput by up to 12% where the aircraft traffic mix is predominantly medium aircraft. ROCAT is especially useful where reduced wake separation using the European wake. The solution re-categorisation (RECAT-EU) scheme is inefficient due to the lack of wide-body aircraft types in the traffic mix. The solution succeeds in developing runway occupancy minima through big data analytics to identify a runway occupancy time per aircraft type using machine learning techniques and historical data. An air traffic control decision-support tool called optimised runway delivery (ORD) (see solution PJ.02-01-01) enables controllers to deliver a change in the separation minima used by controllers separating aircraft on final approach.

EUROCONTROL is working on a specification document for ROCAT in a first step toward the standardisation.

The solution was validated through a real-time simulation in Zurich airport and TMA environments focusing on a range of objectives, such as the operational feasibility, the acceptability of the tool by controllers, safety, human performance and the capacity. It showed that the use of the ORD tool with the solution and a wake vortex pairwise separation scheme (per aircraft type) was operationally feasible and acceptable in segregated runway operations. It also resulted in fewer separation infringements and missed approaches, and controller workload was reduced even though more aircraft were handled by controllers per hour.

The solution is ready for industrialisation and has been implemented in Switzerland and Ireland.



SJU references:
#22/ Release 5

EFFICIENT PLANNING AROUND THE AIRPORT

Automated assistance to controllers for surface movement planning and routing

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BENEFITS

- **Improved predictability**
- **Enhanced safety**
- **Increased capacity**
- **Improved taxi times resulting in reduced fuel burn**

The SESAR surface route planning function automatically generates taxi routes which are then displayed on the controller working position. The software uses flight plans and current operational data to calculate the optimum route for each aircraft. It also calculates the taxi time, which can then be used for departure planning purposes. The controller can graphically edit the route before relaying it to the pilot by voice, or where possible by datalink.

By generating an electronic route plan, the information can be shared not just with the cockpit, but also with the airline operations centre, air traffic control and other operators on the airfield. It is less prone to error than route plans agreed solely based on controller/pilot communication, and it increases air navigation service productivity. The route plan is also available for use with other solutions such as enhanced guidance assistance tools (through airport moving maps in aircraft and vehicles or through the airfield ground lighting) to provide guidance instructions for pilots or vehicle drivers on the airfield.

Trials revealed a reduction in variability between the planned and actual taxi time compared with current operating methods. Efficiency of surface operations is also improved since pilots and vehicle drivers can receive optimum route plans. Safety is also enhanced, particularly in low visibility, as controllers can rely on a graphical display of the routes assigned to aircraft and vehicles.

This SESAR solution is available for industrialisation.

The route planning functionality allows controllers to graphically edit routes and automatically compute estimated taxi times, contributing to more predictable surface operations

This solution is linked to EUROCAE standards ED-87C and ED-87D



IMPROVED COMMUNICATIONS THANKS TO DATALINK

D-TAXI service for controller-pilot datalink communications (CPDLC) application

SJU references:
#23/Release 5



Radio channels become congested and hard to access during periods of busy traffic. Yet the majority of transmissions are routine exchanges between the controller and the flight deck to confirm instructions such as pushback clearance, start-up and taxi instructions. Datalink provides a more efficient means to relay these messages and is less prone to error.

Aircraft already use datalink in oceanic airspace to send position updates and request route changes, and the technology even now delivers pre-departure instructions to pilots at the gate. SESAR is testing message exchanges on the airfield using controller-pilot datalink communications (CPDLC) on board modern aircraft. The service is supported at some airports with advanced controller working positions, and simulations are also underway looking at protocols and operational procedures. The delivery by datalink of information and clearances during the taxi phase is known as D-TAXI. The solution aims to reduce voice communications by exchanging non-critical message between controllers and flight crew by datalink. Radio remains available at any time and is still used on first contact with the controller for radio check and for safety or time critical clearances like line-up and take-off.

A combination of simulations and live trials assessed the performance of the solution in different traffic densities, with different levels of aircraft equipage. Datalink messages were exchanged to initiate start-up, push back, taxi, revised taxi and further route information (such as de-icing). The exercises also used SESAR routing and planning functions to obtain the most suitable taxi route. The activity aims to improve the safety of surface movements.

This solution is available for industrialisation.

This service aims to reduce radio transmissions by exchanging routine and non-safety critical messages by datalink

This solution is linked to RTCA and EUROCAE standards, namely DO-350A/ED-228A, DO-351A/ED-229B

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BENEFITS

- Provides reliable, repeatable message sets for non-safety critical exchanges
- Frees up congested radio channels enhances safety at busy airports
- Delivers instructions more effectively, allowing the pilot and controller to focus on other operational issues



SJU references:
#26/Release 5

TAXI ROUTE DISPLAY FOR PILOTS

Manual taxi routing function

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BENEFITS

- **Enhanced safety**
- **Improved predictability**
- **Increased efficiency in surface operations**
- **Reduced fuel burn and emissions**

Navigating the route between the departure gate and the runway can be complex and becomes harder during low-visibility conditions or at night. To provide extra guidance - in addition to today's airfield signage and ground lighting - SESAR is developing other tools to help the pilot.

Presenting a graphical display of the taxi route instructions received from air traffic control provides another means for the flight crew to check they are following the right route. The on-board moving map of the airfield can be overlaid with the taxi route so the pilot can see exactly where the aircraft is in relation to the cleared route. If the taxi clearance is sent via datalink, through the D-TAXI service, the corresponding message is interpreted and translated as a graphical path by the on-board moving map database. If the taxi clearance is sent via voice, the flight crew can enter it manually into the airport moving map.

The solution uses technology, such as the electronic route planning system the controller employs, to select the optimum taxi route. It also makes use of controller-pilot datalink communications (CPDLC) to relay the route to the cockpit, and could be linked with airport safety nets to warn of potential hazards. The graphical display of the taxi route instructions increases the flight crew's situational awareness, notably in low-visibility conditions and at aerodromes with which they are not familiar. The solution provides an extra layer of safety for the flight crew, in addition to visual signals and voice communications. Aircraft are more likely to comply with taxi route instructions without delay.

A graphical display of the taxi route on the airport moving map increases the flight crew's situational awareness, notably in low-visibility conditions or an airport with which they are not familiar

This SESAR Solution is available for industrialisation.



FOLLOW-THE-GREENS

Guidance assistance through airfield ground lighting

SJU references:
#47/ Release 5



Airfield ground lighting offers a unique opportunity to guide aircraft and vehicles around the airport. By linking the lighting infrastructure with the taxi route management system, the airport can provide an unambiguous route for the flight crew and vehicle driver to follow.

The solution requires advanced technology within the lights themselves, and in the ramp control tower. The airfield lighting control system needs to turn on the lights ahead of an aircraft, and off immediately behind. To achieve this, taxiway centre line lights are automatically and progressively switched on in segments (or individually) as the aircraft (or the vehicle) moves along its assigned route. Pilots and vehicle drivers receive a single instruction to 'follow-the-greens' from air traffic control (ATC). If stop bars are implemented to protect no-go areas, they are also automatically commanded. The solution also relies on the surface movement guidance and control system to provide accurate aircraft position data.

The solution improves the safety of surface operations, especially during low-visibility conditions, through a reduction of runway incursions, taxi route deviations and holding position overruns. It increases situational awareness and improves the predictability of surface movement through a reduction in the variability of taxi times. The fewer speed changes also result in lower fuel consumption. As taxi speeds are globally increased, apron throughput is improved.

SESAR validations used a combination of simulation exercises, shadow-mode trials using vehicles to represent aircraft and several live trials with commercial aircraft. In all cases, the trials showed that the use of the lighting system can significantly help to reduce taxi times and also reduce the duration of stops during taxiing, improving efficiency. Fewer radio transmissions were required, freeing up controllers' time for other tasks. Based on more than 650 movements, one of the airports at which the solution was validated recorded a 25 % reduction in taxi time, while radio transmissions fell by the same amount. Clearance delays (the time between the pilot's push back request and actual clearance) fell by two thirds.

This solution is now available for industrialisation.

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BENEFITS

- Improved predictability
- Enhanced safety
- Reduced fuel burn, noise and emissions
- Increased apron throughput

This solution couples taxi route management with the airfield ground lighting, in order to provide flight crew and vehicle drivers with supplementary means of guidance

This solution is linked to EUROCAE standards ED-87C and ED-87D



SJU references:
#48/ Release 5

ENHANCING SAFETY WITH VIRTUAL STOP BARS

Virtual block control in low-visibility procedures

STAKEHOLDERS

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BENEFITS

- Improved predictability
- Enhanced safety
- Reduced fuel burn and emissions

Supporting controllers and flight crew is especially important in low-visibility conditions. A line of red lights, known as stop bars, are already used to prevent aircraft entering a runway without air traffic control clearance. In addition to these physical safety nets, SESAR is advancing a novel virtual stop bar solution.

During low-visibility conditions, the ground controller can introduce procedural control to maintain safe separation, requiring clearance for aircraft to enter different areas. SESAR has developed virtual stop bars to support the ground controller in providing surface movement guidance at these times, displaying red stop lights on the controller's display. The virtual stop bars can be used by the controller to reduce block sizes according to the conditions.

If the airport surface surveillance system identifies an infringement, the controller's display receives an alert. These virtual stop bars are a valuable defence against aircraft and vehicles inadvertently entering an area without clearance from the ground controller. Providing alerts on the ground controller's display enhances safety.

Real-time simulations tested the solution also investigating the use of datalink communications with aircraft as well as airfield vehicles.

This solution is planned for implementation in Gdańsk.

Virtual block control is an operational concept for improving weather resilience and safety at airports

Virtual stop bars alert controllers of any kind of unauthorised movement by aircraft or vehicles in the area of the runway



ENHANCING SAFETY AT BUSY AIRPORTS

SJU references:
#02/Release 5

Airport safety nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances



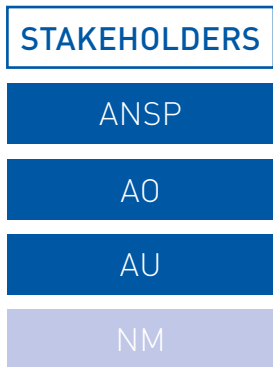
As traffic rises, airports face the challenge of more ground operations and surface traffic moving across runways, taxiways and aprons. In addition to safety initiatives driven by ICAO, a series of automation tools have been developed by SESAR partners to provide valuable safety nets in this area.

As part of advanced surface movement guidance and control systems (A-SMGCS) activities, new generation automation systems have been included in validations to see how various tools can operate together to provide integrated airport safety nets. These validations assessed the relevance of alerts to tower controllers in case of conflicting clearances (e.g. line up and landing clearances given at the same time on the same runway) and in case of mobile behaviour (i.e. aircraft or vehicle) not complying with ATC instructions or procedures.

The introduction of electronic flight strips in many control towers means that instructions given by a controller are available electronically and can be integrated with other data such as flight plan, surveillance, routing and published rules and procedures. The integration of this data allows the system to monitor the information and alert the controller when inconsistencies are detected.

This solution highlights potential conflicts much sooner than current safety nets for runway operations which rely only on surveillance data to trigger an alarm. Moreover, the automatic conflicting ATC clearances (CATC) alert system can be configured to detect non-conformance to ATC instructions or procedures anywhere in the movement area.

This SESAR solution is available for industrialisation. These airport safety nets are part of synchronised deployment plans across Europe.



BENEFITS

- Increased situational awareness
- Improved safety in airport operations
- Enhanced safety and situational awareness





SJU references:
#70/Release 3

SURFACE SAFETY IN ALL WEATHER CONDITIONS

Enhanced ground controller situational awareness in all weather conditions

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BENEFITS

- **Operational acceptance of airport safety nets**
- **Increased situational awareness in low visibility conditions**
- **Enhanced safety thanks to the generation of real alerts**

Ground controllers face the challenge of managing not just arriving and departing aircraft, but also guiding the service and emergency vehicles that support safe operations at the airfield. Adding surface safety nets to the controller's display offers a means to provide early warning of potential conflict situations.

Developing and implementing airport safety tools is fundamental to SESAR objectives to triple capacity and increase safety by a factor of 10. Safety nets rely on information received from surface surveillance (automatic dependent surveillance – broadcast (ADS-B) messages emitted by aircraft and vehicles), flight data including clearances given, and taxi routes assigned. Built-in monitoring rules can be configured to an individual aerodrome in order to trigger alerts for the main conflict situations. Warnings can also be activated when meteorological data signals adverse weather.

The solution develops further ADS-B applications to improve ground surveillance systems in terms of safety, performance, interoperability and security. Data quality is increased with regard to the current surveillance system by means of improved surveillance data. The ADS-B ground station is enhanced to check the validity of the ADS-B derived data and to discard possible spoofing messages as well as messages transmitted by erratic ADS-B transponders, guaranteeing an improvement of the surveillance in terms of security and safety

SESAR validation activities demonstrated an increased situational awareness in low-visibility conditions. As a result of the operational acceptance of the research, the solutions were seen as suitable for development as part of surface movement guidance and control activity.

This solution is ready for industrialisation. The solution has been implemented in 42 airports across Europe.

The solution provides the controller with the position and automatic identity of all relevant aircraft and vehicles in the movement area

Developing and implementing airport safety tools is fundamental to SESAR objectives to triple capacity and increase safety by a factor of 10





VISUAL SIGNALS TO SAFEGUARD RUNWAY USERS

Runway status lights

SJU references:
#01/Release 5



Runway incursions are among the greatest risks in airport operations today. By installing lights which automatically alert when it is unsafe to enter a runway, airports can provide runway users with an early warning of a potential hazard.

Major airports rely on surface surveillance systems such as surface movement radar (SMR) to provide the tower controller with a visual picture of surface movements in real time. Adding safety tools for controllers, for example, to highlight non-conformance alerts or route deviation, ensure safe and accurate guidance around the airport by virtue of the advanced surface movement guidance and control system (A-SMGCS). A pilot navigating to and from the runway also relies on visual signage, and this equipment can receive information at the same time as the tower, saving crucial seconds.

Runway status lights (RWSL) include three types of high intensity LED lights: runway entrance lights (RELs), warning an aircraft about to enter the runway from a taxiway that the runway is not safe to enter, take-off hold lights (THLs) warning pilots that it is not safe to take-off from the runway, and runway intersection lights (RILs) to prevent flight crew and vehicle drivers from entering or crossing an active runway that is already occupied. Embedded in the pavement, the red warning lights alert the pilot or the vehicle driver the instant the runway is unsafe due to the detection of mobile behaviour by the A-SMGCS.

Runway status lights (RWSL) are fully automatic and require no input from controllers, airport operators or flight crew

Linking intelligence about airfield surface movements with airfield lighting enhances surface safety for aircraft and vehicle movements

The RWSL are unique in providing instant visual alerts, and operate simultaneously with, and in addition to, other safety nets such as on-board alerts and air traffic control safety nets. The system improves awareness of runway usage, and reduces the risk of collisions on the runway. It applies equally to aircraft and vehicle traffic and does not require additional equipment in the cockpit or driver's cab.

This solution is now implemented in Paris Charles de Gaulle airport.

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BENEFITS

- **Enhanced runway safety**
- **Increased situational awareness**





SJU references:
#04/Release 5

PROVIDING VEHICLE DRIVERS WITH ENHANCED VISUAL TOOLS

Enhanced traffic situational awareness and airport safety nets for vehicle drivers

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BENEFITS

- Increased situational awareness
- Increased safety in airport operations

Driving an airfield vehicle on the airport should be straightforward in normal operational conditions. But how do you ensure you are following the correct route when in dense fog, or at night, or when an unforeseen event occurs? And more importantly, how do you ensure that you are not entering a safety critical area without a clearance, putting you and the other mobiles' safety at risk?

Busy airports monitor airfield activity using a range of sensors and tracking systems. This information can also be used by vehicle drivers to improve safety. By fitting a screen in the vehicle, the driver can access an airport moving map, can see information regarding surrounding traffic, and can receive alerts if a dangerous situation arises. Warnings can include those related to possible collisions with an aircraft on a runway or taxiway, infringements of a runway, or a closed or restricted area.

SESAR has carried out a series of validation exercises in different locations in various traffic and visibility conditions. Alerts were generated either by an on-board system on the dashboard, or were uplinked from the ground aerodrome surveillance system enhanced with a dedicated function calculating alert situations relevant for vehicle drivers.

The trials developed the requirements for the display of information related to the surrounding traffic, including aircraft and vehicles operating on or near an active runway. The tests also established connectivity between the central system and vehicle, as well as the use of mobile devices.

This solution is part of Europe-wide synchronised deployment.

SESAR demonstrated through extensive live trials the significant benefits of this SESAR Solution in terms of situational awareness and safety

This solution is linked to EUROCAE standards ED-102, ED-102A and ED-102+

EASA is reviewing a proposed amendment to the existing requirements for time-based and distance-based pairwise separations for arrivals under Reg. EC 2017/373 Annex IV Part-ATS





PILOT WARNINGS HELP TO AVOID AIRFIELD COLLISIONS

SJU references:
#PJ.03b-05/
Release 9

Traffic alerts for pilots for airport operations



Traditionally pilots rely on their line of sight and air traffic control guidance to avoid collisions. Thanks to airport surface surveillance sensors and ground safety nets controllers can warn pilots of potential conflict. However, these systems are not usually available at smaller airports and there is currently no aircraft system to prevent runway incursions.

This solution is designed to provide a very last warning to pilots of imminent collision on runways and taxiways based on software on board the aircraft. Specifically, the system analyses aircraft position data and calculates factors, such as time to collision, using specialised algorithms before alerting pilots to surrounding aircraft. The improvement is split into two validated implementations: A standard version for mainline aircraft which provides the flight crew with an audio alarm; and a business aircraft edition which, in addition to the aural alerts and alarms, prompts a visual alert in the cockpit, on the airport moving map for the equipped aircraft.

Sufficient ADS-B performance is a key enabler, which is why work was undertaken in SESAR 1 and then followed up in SESAR 2020 (by PJ.28, a very large-scale demo) to assess ADS-B performance, including data quality and acceptable rate of missed, false and nuisance alerts.

Fast-time and real-time exercises were carried out and system prototypes developed for use in flight tests which tested both mainline and business aircraft operational specificities. The validations included algorithms performance as well as human factors, human-machine interface evaluations and a workshop with pilots and controllers.

The traffic alerts are in-line with requirements given by EASA CS-25.13.22 and this material will support certification

The results showed the human performance objectives were met and the algorithms and ADS-B data is robust. Additional activities, such as very large-scale demonstrations, are needed for the solution to progress towards industrialisation and certification, to address ADS-B data quality analysis, pilot training, phraseology and studies using alternative broadcast traffic information. SESAR also recommends standardisation of the functions to expand the benefits. The more aircraft are equipped, the greater the coverage of incidents.

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BENEFITS

- Improved airport surface safety in all weather
- Better situational awareness for flight crew
- Reduced risk of runway incursions



A BASELINE FOR ON-TIME DEPARTURE

Departure manager (DMAN) baseline for integrated AMAN DMAN

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BENEFITS

- Improved predictability and stability of departure sequence, start-up approval time and off-time blocks
- Enhanced tactical runway scheduling
- Reduced waiting and taxi times and runway delays
- Significant reduction in fuel burn and CO₂ emissions

Waiting in a queue for take-off burns unnecessary fuel, generates delay and unpredictability and is frustrating for passengers. Fortunately, we encounter these queues less and less, due to a large extent to the way the departure management process is transforming departure time from an informed estimate into a precise art.

The departure manager (DMAN) tool takes into account the scheduled departure times, slot constraints, runway constraints and airport factors. In doing so, it improves traffic predictability, cost efficiency and environmental sustainability, as well as safety. By taking into consideration information such as the aircraft's readiness to leave its parking stand, runway capacity and slot constraints, tower controllers can optimise the pre-departure sequence.

In order to calculate reliable sequences, DMAN needs access to accurate information about the status of individual flights and airport resources from different systems. The airport collaborative decision-making (A-CDM) platform supports this information exchange. For example, the airline or ground handler can provide the target off-block time (TOBT), while the tower controller uses tables which generate variable taxi times to achieve the target take-off time (TTOT). Information about departure slots or calculated take-off times (CTOTs) is sourced from the Network Manager, responsible for flow control across the whole of Europe.

SESAR's baseline DMAN was validated in a series of live trials with a particular focus on delay reduction. Controllers were able to establish pre-departure sequences by using DMAN in conjunction with airport collaborative decision-making procedures involving local airport and airline partners. The system provides a baseline for further development of DMAN procedures, taking advantage of the wider adoption of airport collaborative decision making among stakeholders. The basic operational concept also supports DMAN integration with arrival manager (AMAN) and advanced surface movement guidance and control system (A-SMGCS).

The trials demonstrated improved performance in terms of predictability of off-block time by 7.8 %, with 85 % of flights achieving the five-minute window available. It decreased average taxi times by 9 %, and improved adherence to flow management slots, with 81 % of flights departing on their allocated slot compared with 76 % prior to DMAN. The solution contributed to average reduction of 14.6 kg of fuel per flight, and also supports enhanced tactical scheduling.

The solution has been implemented in 29 locations across Europe, and is part of synchronised deployment.

DMAN lends itself to tactical scheduling by calculating optimum pre-departure sequences based on information provided by airport, airline and air traffic control sources (A-CDM processes)

This solution is linked to EUROCAE standards ED-87C and ED-87D





IMPROVING ON-TIME DEPARTURE

Pre-departure sequencing supported by route planning

SJU references:
#53/Release 4



A row of aircraft lined up ready to depart might deliver maximum runway efficiency, but contributes little to efficient fuel use and reducing noise and emissions. While all departures are carefully planned, SESAR is looking at ways to enhance the process and introduce efficiencies right from push-back.

Pre-departure management delivers optimal traffic flow to the runway by factoring in accurate taxi time forecasts and route planning derived from static data. This can help to reduce waiting time at runway holding points, and improve take-off time predictability. Accuracy can be improved if the departure manager (DMAN) takes into consideration data provided by the advanced surface movement guidance and control system (A-SMGCS). This can account for where the aircraft is parked, taxi route length and tactical adjustments such as temporary restrictions. Just how much current operations - which rely on collaborative decision making to estimate taxi times - can be enhanced by access to dynamic data depends upon the individual airport and the quality of data available.

SESAR trials using this dynamic route planning information resulted in more accurate calculations of the departure sequence, and improved predictability and stability of both target times and actual times. In particular, the sequence assigned to each flight for target start-up time, and for target take-off time, improved with the use of route planning information. For busy single runway airports, predictable operations result in better use of the available capacity.

Trials showed that the solution leads to reduced waiting time at the runway holding point, saving fuel and improving efficiency. It also increases the accuracy of estimated taxi time and hence take-off time predictability, which in turn allows the aircraft to adhere to target take-off time. Finally, the more stable departure sequence benefits airport operations overall, and is used in turn by the Network Manager to optimise traffic flow.

This solution is available for industrialisation. DMAN synchronised with pre-departure sequencing is part of synchronised deployment plans.

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BENEFITS

- **Reduced waiting time at the runway holding point, which saves fuel and allows air navigation service efficiency**
- **Increased accuracy of taxi time-out prediction and hence take-off time predictability, which in turn allows the aircraft to adhere to their target take-off time (TTOT)**
- **Provision of a more stable pre-departure sequence**

Airports where taxi route lengths can vary significantly benefit the most from taxi times calculated using planning information from the surface movement guidance and control system

This solution is linked to EUROCAE standards ED-87C and ED-87D





SJU references:
#54/Release 4

EXTENDING THE PLANNING HORIZON

Flow-based integration of arrival and departure management

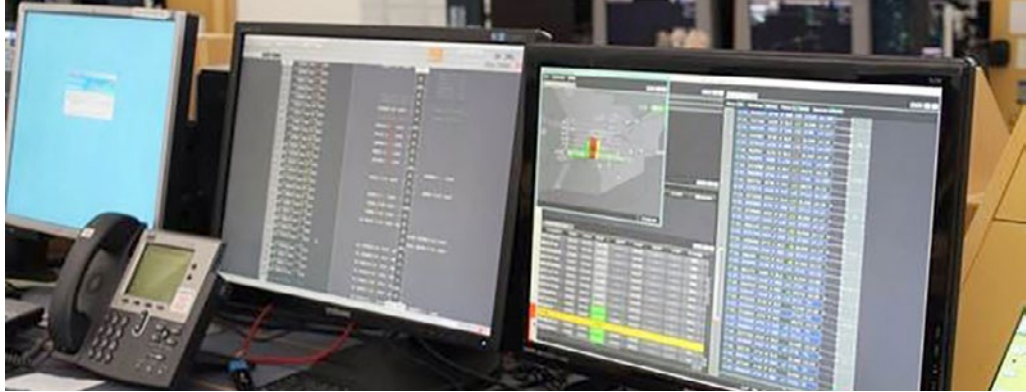
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BENEFITS

- **Increased predictability resulting in increased runway throughput**
- **Reduced fuel burn**

Knowing exactly when an aircraft is due to arrive has a direct impact on airport efficiency, especially if arrivals and departures are handled on the same runway, or on dependent runways. Improving coordination between en-route controllers, approach and tower controllers results in more accurate information about the arrival sequence that can lead to more predictable airport operations.

By integrating the activities of the arrival manager (AMAN) and the departure manager (DMAN) tools, an optimisation algorithm can calculate the ideal traffic flow that takes account of both arriving and departing aircraft. Departure flow to the runway is managed by the pre-departure sequencing planning tool, while arrival flow to the runway is managed by arrival metering. Arrival and departure flows to the same runway (or for dependent runways) are integrated by setting up a fixed arrival-departure pattern for defined periods. The successive pattern might be chosen by the operators or provided by an optimisation algorithm which takes account of arrival and departure demand. The solution is an enabler for accurate runway sequencing and facilitates long-range planning such as extended arrival management. It results in increased predictability, which leads to high capacity and less fuel burn, and better coordination between controllers.

The concept of coupling AMAN-DMAN to produce an accurate runway sequence has been validated at an exceptionally busy single-runway airport. The advanced surface movement guidance and control system also provided data on target push-back, taxi- and take-off times. The tests resulted in increased predictability in terms of target take-off time and target landing time, because the sequence offered by the system contributed to more accurate controller clearances.

Controllers delivered positive feedback about the integrated sequence, information sharing and the ability to input multiple runway patterns

This solution is part of Europe-wide synchronised deployment.





INTEGRATED ARRIVAL/DEPARTURE PLANNING TOOLS HELP TO INCREASE RUNWAY THROUGHPUT

SJU references:
#PJ.02-08-01/
Release9

Integrated runway sequence for full traffic optimisation on single and multiple runway airports



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Efficient use of runway capacity helps to reduce queuing on approach to the airport and on the ground and results in lower fuel consumption and cost to airspace users. Assisted by integrated arrival and departure planning tools, tower and approach controllers can optimise runway configuration and sequencing while maintaining safety and human performance. This solution applies to single and multiple runways, interdependent runway layouts and mixed mode operations.

BENEFITS

- Raises capacity by optimising arrival and/or departure sequencing
- Reduces environmental impact and fuel consumption
- Improves controller productivity
- Improves sequence stability

The concept relies on early and dynamic planning of arrival and departures using trajectory-based integrated runway sequencing. This is achieved using accurate target take-off times (TTOTs) and target landing times (TLDTs) in a look ahead time horizon period of approximately one hour, depending upon local implementation. The integrated runway sequence for arrival flights is linked with airport collaboration decision making (A-CDM) procedures for departures to provide dynamic assistance to controllers.

The integrated runway sequence function calculates an optimised runway sequence including arrival and departure flights linked to the arrival trajectory prediction (to provide estimated landing times) and departure management (based on estimated take-off times). This contributes to increased airport capacity, and leads to more predictable and punctual arrival and departure times as well as fuel efficiency for airspace users.

Compliant with minimum technical specification for Airport-CDM EUROCAE ED-141

SESAR JU partners completed a series of validations including two real-time simulations in Geneva and Stockholm-Arlanda airport environments, and a fast-time simulation in Roma-Fiumicino airport environment, to validate improvements in fuel efficiency and airport capacity when using an integrated runway sequence function. The results also showed an improvement in human performance and enhanced situational awareness. The validation proved the concept is mature and delivers improvements in predictability and punctuality in a high-density airport environment. In the next stage, the procedures can be refined locally at airport level with demonstration activities.

The solution is ready for industrialisation and conforms with the EUROCAE standard ED-141 A-CDM technical specifications.



SJU references:
#PJ.02-08-02/
Release9

AIRPORTS WITH MULTIPLE RUNWAYS BENEFIT FROM INTEGRATED PLANNING TOOLS

Optimised use of runway configuration for multiple runway airports

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BENEFITS

- **Raises capacity by optimising arrival and/or departure sequencing**
- **Reduces environmental impact and fuel consumption**
- **Improves controller productivity**
- **Improves sequence stability**

Airports with more than one runway stand to benefit from dynamic assistance tools that increase the predictability of runway capacity and contribute to more efficient configuration of arrivals and departures. The runway manager (RMAN) tool which developments started under SESAR 1 is used by the tower supervisor to determine the optimal runway configuration and distribution of demand according to capacity and local constraints. Since the demand is continuously evolving along time, the RMAN continuously computes the optimal runway configuration and the associated forecasted landing (FLDT) and take-off times (FTOT) of arrival and departures flights that maximises the runway throughput.

SESAR 2020 combines the runway manager and the integrated runway sequence tool to further improve flight punctuality and minimise delay. The forecasted times calculated by the RMAN are provided to the Integrated runway sequence using them to calculate the final target times and detect any imbalances. The concept is supported by improved prediction about runway occupancy times provided by ground-based systems, which measure the time taken to line up, take-off, land and vacate the runway.

SESAR validated the concept of combining runway manager and integrated runway sequence tools managing arrivals and departures at a large airport during several exercises, in particular a real-time simulation in Barcelona-El Prat airport environment. During the validation exercise, integrating the tools was shown as technically and operationally feasible with updated runway sequence information presented to the controller. A stable and reliable arrival/departure sequence was produced. Average delay was reduced as a result of extending the planning horizon, and punctuality improved. Average flight time was reduced for arrivals as the runway manager was able to take advantage of free gaps in the sequence.

The positive results support transition to industrialisation for this solution, along with a development of an appropriate human machine interface to present the integrated runway sequence order for arrivals and departures.

Compliant with minimum technical specification for Airport-CDM EUROCAE ED-141

The solution is available for industrialisation and has been implemented in France.



REMOTE TOWER SERVICES FOR SMALL AIRPORTS

ATC and AFIS service in a single low-density aerodrome from a remote controller working position (CWP)

SJU references:
#71/Release 3



Small or local airports are a life-line for a local economy, however they cannot always afford to operate a control tower around the clock. SESAR's remote tower services offer the means to provide air traffic services in a cost-efficient way to such airports, as well as non-towered ones.

By installing sensors (mainly video cameras) around the airfield, the operator can monitor activity such as runway occupancy, weather, and visibility in real time. Data is relayed back to a remote control centre where a qualified operator is on hand to provide aerodrome flight information services (AFIS) or air traffic control services for arrivals and departures. With access to a range of visual, audio, and meteorological data, the remote facility can provide services which may not be available onsite around the clock.

In a series of real-time simulations and passive shadow-mode trials (i.e. the controllers participating in the validation 'shadowing' the instructions given by the operational controllers in the real tower), controllers used high resolution imagery and enhanced functionalities to provide advisory services to a remote location. As a result, safety was maintained in normal and degraded conditions and controllers welcomed the enhanced visual tools. The concept supports extended operational hours with lower overall staffing costs. It also supports development of regional economies.

The solution is available for industrialisation. Conclusive validation results prompted Sweden to build the world's first remotely operated tower at Örnsköldsvik, controlled remotely from Sundsvall centre over 150 km away. The facility was fully certified by the Swedish Aviation Authority in 2014. The solution is now implemented in Kiruna from Stockholm RTC (Sweden) Örnsköldsvik, Sundsvall, Linköping and Scandinavian Mountains Airport from Sundsvall RTC (Sweden) Røst, Vardø, Hasvik, Berlevåg from Bodø RTC (Norway).

In 2014, the world's first remotely-operated tower was opened at Örnsköldsvik, controlled remotely from Sundsvall centre over 150 km away

Operational standards for remote tower services (addressed by EUROCAE WG-100) currently match those for real operations and approval is based on the same service delivery requirements as existing ICAO rules

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BENEFITS

- Increased cost efficiency
- Increased accessibility to and support for regional economies





SJU references:
#12/Release 5

REMOTE TOWER SERVICES BENEFIT MEDIUM-SIZED AIRPORTS

Single remote tower operations for medium traffic volumes

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BENEFITS

■ Increased cost efficiency

Conventional control towers are expensive to operate and maintain, and even at a medium-sized airport can become too costly if the number of flights is insufficient to cover the running costs. SESAR's remote tower services offer the possibility to enhance safety and efficiency at airports where it is too expensive to build, maintain and staff conventional tower facilities and services. The solution is already deployed at small airports, and is under test at medium-sized airports.

Providing air traffic control services from a remote location can spread staffing costs, improve service continuity with the option to extend hours of service, and share training and support costs. The out-of-the-window view from the tower can be captured and reproduced at a remote facility where controllers can access all the information usually found in the tower. The visual reproduction can also be overlaid with information from additional sources and enhanced through technology for use in all visibility conditions. In addition, the controllers have access to all the necessary remote controls, including communications, lighting, flight data, and meteorological information.

Tests have demonstrated the solution's feasibility using different technology and sensors. Sophisticated camera equipment, some sourced from the military sector, are considered in the scope of this solution; while day/night cameras, infrared, and pan-tilt-zoom functions deliver the level of detail and accuracy required to safely provide ATS services. The tower-like environment at the remote facility can be enhanced with visual alerts, track labels added to flight targets, and hot spots regularly camera-checked to deliver additional safety features.

Single remote towers offer an efficient way to deploy operational staff resources by means of a remote tower centre providing single tower services to a number of airports

The standardisation work on remote towers is addressed by EUROCAE WG-100

Shadow-mode exercises used a video-based panorama camera system as well as infrared technology to give controllers a detailed view of the airfield. The tests provided enhanced views of the airfield and terminal area, even during adverse weather conditions and at night. Single airport operations will apply in each case, but controllers will have the option to cross-train for more than one airport.

The SESAR Solution is available for industrialisation and is implemented in Saarbrücken and London City.





MANAGING MULTIPLE SMALL AIRPORTS, REMOTELY

Remote tower for two low-density aerodromes

SJU references:
#52/Release 4



Having proved controllers can provide air traffic control services to an airport remotely, SESAR validated the feasibility of providing simultaneous services to two airports from a single location.

The solution offers new possibilities for small or local airports where building, maintaining, and staffing a conventional tower is unaffordable. It promises more efficient and cost-effective deployment of operational resources, improving service continuity and maintaining safety at the same time.

The concept draws on a range of advanced technology, including high-definition cameras, Infrared, and pan-tilt-zoom cameras to deliver the information the controller wants to see in real time. Video camera data can be integrated with existing surveillance sources to identify and track targets.

In SESAR validations, a control facility provided controllers with an out-of-the-window view and working position that supported two low-traffic density airports located remotely, and allowed the controller to switch seamlessly between the two. Like an onsite manned tower, the controller has access to data from supplementary sensors and software tools that significantly enhance the visual information on display, and SESAR partners have identified a core set of functionalities needed to deliver air traffic services to multiple airports.

This solution is available for industrialisation and remote towers are planned in Germany (Saarbrücken, Erfurt, and Dresden) and Norway (15 airports). See also Solution PJ.05-02 on the multiple remote tower module.

Multiple remotely controlled airports contribute to SESAR cost-efficiency performance targets

The standardisation work on remote towers is addressed by EUROCAE WG-100

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BENEFITS

- Operational and technology-related cost efficiency





SJU references:
#13/ Release 5

PROVIDING BACKUP REMOTELY

Remotely-provided air traffic services for contingency situations at aerodromes

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BENEFITS

- **Increased cost efficiency**
- **Improved resilience in degraded situations**

Security alerts can shut down control towers. How does the airport ensure minimum disruption in an emergency? This question has been addressed by SESAR looking at contingency situations for airports.

Contingency towers are not new, and already operate at London, Brussels, and near-completion at Budapest. They provide operational resilience and safety assurance should the primary tower be compromised. This solution brings additional technology into play, and addresses issues including accessibility, training and security to deliver more resilience and a higher efficiency in degraded situations.

A remote facility offers a cost-efficient alternative to building new infrastructure onsite. It can provide air traffic control services as close to full-operating capacity as possible, and can feature additional information feeds to enhance the data available. Most importantly, it can maintain safe flight operations, with minimum disruption to the flights operating to and from the airport affected.

Shadow-mode exercises have been carried out to examine exactly how a remote tower facility can provide contingency services at medium-sized airports. The exercises assessed the transition time necessary to switch from the primary tower to the contingency facility, what level of service can be provided in the absence of an out-of-the-window view, and what information can be accessed by controllers. They also looked at controller workload, situational awareness, and human performance.

The solution is available for industrialisation and has been implemented in Budapest and Jersey.

Contingency towers deliver increased operational resilience for medium-sized airports

Building infrastructure off-site is more cost-efficient, and easier to maintain

The standardisation work on remote towers is addressed by EUROCAE WG-100





SMALL AIRPORTS BENEFIT FROM MULTIPLE REMOTE TOWER SERVICES

SJU references:
#PJ.05-02/Release
9

Multiple remote tower module



Control towers are expensive to build and maintain but the services they provide are important for the prosperity of the local community and for maintaining safe air traffic operations. With a proven return on investment, remote towers offer a safe and sustainable solution to low-density airports handling less than 40,000 movements a year. Multiple remote tower module (MRTM) has the added advantage of enabling these airports to not only maintain their operations, but to become integrated into a broader network.

The remote tower concept has expanded since the first module gained certification in Sweden in 2015 and latest SESAR research validates advanced features necessary for controllers to maintain situational awareness for two or three airports simultaneously. The Multiple remote tower module (MRTM) solution applies to airports typically handling up to 40,000 annual movements but the local traffic characteristics, environment and ANSP constraints and preferences will determine how the MRTM can be deployed. It is applicable to all types of airspace users including general aviation, rotorcraft and remotely piloted systems (RPAS) and builds on multiple remote tower research carried out in SESAR 1.

SESAR 2020 partners carried out four real-time simulations and one shadow mode trial using four different validation platforms addressing various airport environments. The exercises tested human performance, visual information displays, advanced voice services, technical support systems, and safety performance. The results showed the MTRM could handle the same traffic volume as the single remote tower with up to 25% fewer controllers. Additionally, different types of aerodromes could be paired together in the MTRM module, and in cases of traffic overload, aerodromes could be split between modules. In the examples, traffic complexity and mix of aircraft type directly impacts workload, as does weather and airport layout.

Standardisation activities from SDM-0201 are already in place in the ED-240A and RMT.0624 together with STD-HNA-04 and -05.

SESAR recommends EASA updates European safety regulations related to multiple tower services and related risks in multiple mode of operation, taking into account the increased level of maturity. SESAR also encourages the use of support tools in place of voice for sector coordination and recognises the need to harmonise procedures, alerts and alarms at different aerodromes. The solution is planned for Sweden, Norway and Germany.

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BENEFITS

- **Cost-efficiency gain of up to 25% in controller resources**
- **Safety and capacity are maintained**



SJU references:
#61/ Release 1

LINKING SMALL AIRPORTS TO THE NETWORK

A low-cost and simple departure data entry panel for the airport controller working position

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BENEFITS

- **Significant improvement in traffic predictability**
- **Increased network capacity**
- **Better runway configuration and management**

Many airports in Europe, particularly regional and small airports, are not equipped with electronic flight data processing systems (eFDPs) but rely on paper flight strips and voice communications. As a result, the integration of these airports into the air traffic management network is often limited and leads to a lack of predictability of air traffic from these airports. SESAR has developed affordable ways to link these airports to the wider network.

The use of a simple airport departure data entry panel (ADDEP) provides a low-cost solution to compute and share aircraft electronic pre-departure data across the air traffic management network, between the tower and approach controllers, as well as the tower and the Network Manager. Trials carried out at a small airport tested a standalone panel which the controllers used to input data such as push-back clearance, taxi and cleared for take-off. This ADDEP then generated departure messages which could be used to update the local flow management centre and the Network Manager.

The validation activities showed that the application of the solution improved accuracy of estimated take-off times when compared with operations without the panel. Previously, over 40 % of take-off times were at variance with estimated times (often set hours in advance), and this dropped to less than 10 % when controllers had access to the ADDEP. The extra panel did not impact on safety, and could be easily accommodated by the controller working position.

This solution is implemented in 16 airports in Germany and continental Spain, and on the Canary Islands.

Once an airport has installed an ADDEP application, it can be adapted to provide other services, such as combined arrivals and departures provision for the tower

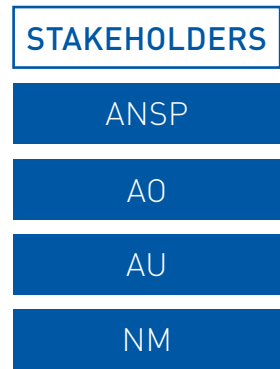




AIRPORTS ARE THE NODES OF THE NETWORK

SJU references:
#21/ Release 5

Airport operations plan (AOP) and its seamless integration with the network operations plan (NOP)



Airports are the nodes of the airspace network, linking flights for seamless traffic flow. They can also act as bottlenecks of the network and need to be integrated into the system as a whole. The network operates according to a pre-defined network operations plan (NOP), so why not airports? SESAR is introducing the additional means to manage airport operations in a collaborative and proactive way, through the airport operations plan (AOP) and the airport operations centre (APOC).

BENEFITS

- Enhanced predictability
- Improved airport resilience/limiting capacity reduction in degraded situations

The AOP is a single, common and collaboratively-agreed rolling plan for an individual airport. The AOP relies on information from different players including airlines, ground handlers, air traffic control, security, emergency services, meteorology and airport management. Set against specific performance targets, the airport monitors the progress of the plan and mitigates the impact of any deviations that may occur.

Daily airport operations are managed by the APOC, which can be a physical facility or a virtual collaboration between stakeholders. The alignment between planned and executed operations is continuously monitored, with changes being made to the AOP as required. As stakeholders update their intentions, or accurate flight progress information is received, the AOP is refined and used to manage resources and coordinate operations. Integration with the NOP extends the planning activities to include air traffic demand and improved target time coordination.

The aim with this solution is to provide processes and tools to maintain airport performance in all operating conditions, and to share information with the wider network. Two principal services are provided by this solution: to establish appropriate performance goals and to monitor the performance during the execution timeframe. Ultimately the AOP and APOC make airports more resilient to disruptions by enhancing the common situational awareness of ATM stakeholders through the sharing of real-time information.

SESAR validations looked in detail at information requirements, alerts and information sharing in order to optimise the use of airport capacity and resources. Real-time simulations as well as shadow-mode exercises were used to validate airport performance monitoring and management. Finally, a live trial took place to integrate landside operations with the airside environment by integrating data related to passenger milestones in the AOP.

The full solution is available for industrialisation and is part of European synchronised deployment.





SJU references:
#116/Release 5

IMPROVED WINTER WEATHER FORECASTING FOR DE-ICING OPERATIONS

De-icing management tool

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BENEFITS

- Improved situational awareness of aircraft de-icing operations
- Increased predictability

The winter season at European airports can last from a few days to many months and during this time de-icing services may be needed. The procedure of applying required de-icing fluids to aircraft at most airports is primarily a business process that takes place between an airline and a specialised ground handling agent. The SESAR de-icing management tool (DMIT) refers to a system capable of improving the predictability of aircraft de-icing operations at European airports by taking data inputs from meteorological service providers and involving the relevant airport stakeholders.

The solution increases the accuracy of information related to when the procedure is going to take place, how long it will take and when the aircraft will be ready to taxi for departure, which is currently calculated by predetermined estimates. The solution means that air traffic controllers no longer need to work without situational awareness of de-icing activities and needing to make their own estimates of when aircraft are ready for departure. The solution envisages that de-icing operations are no longer characterised by the A-CDM concept as 'adverse conditions', i.e. a state that is in need of collaborative recovery procedures, but rather a part of normal operations in the winter period.

The DIMIT allows for the scheduling and monitoring of de-icing operations. It is an internet browser-based tool that addresses three distinct procedures for de-icing:

- Remote de-icing, which occurs at a specific location on the airport away from the parking stand;
- On-stand de-icing, which occurs just before the aircraft leaves its stand; and
- After-push de-icing, which occurs after the aircraft has pushed back from the stand and is positioned to start taxiing after de-icing.

The de-icing coordinator and the de-icing agent can refine the sequence through the DIMIT user interface to account for any ad hoc situations that are not handled by the tool

With the involvement of airport operations data base (AODB), the tool subscribes to flight information and produces information in the form of time stamps for use by coordinators, managing the de-icing of aircraft.

This solution is available for industrialisation. The solution has been implemented in Austria (Vienna), Belgium (Brussels), Denmark, France (Paris Charles de Gaulle), Germany, Italy and Switzerland (Zurich).

The DIMIT produces estimated de-icing time (EDIT), estimated commencement of de-icing time (ECZT) and estimated end of de-icing Time (EEZT) time stamps and publishes these to the A-CDM platform, both improving the quality of de-icing milestone information and increasing common situational awareness for other airport actors



SAFER APPROACH AND DEPARTURE PROCEDURES FOR ROTORCRAFT

SJU references:
#PJ.02-05/Release 9

Independent rotorcraft operations at the airport



Where rotorcraft fly under instrument flight rules (IFR), either due to airspace class or weather conditions, air traffic control currently has to manage these flights in accordance with fixed-wing procedures, often delaying overall throughput at busy airports. This is where SESAR and this solution comes in – it provides specific approach and departure procedures for rotorcraft. The solution is set to improve access to airports for rotorcraft, as well as the efficiency of airport operations where both fixed-wing aircraft and rotorcraft operate and the environmental footprint of rotorcraft at and around such airports.

Rotorcraft-specific independent IFR procedures to/from final approach & take-off areas (FATO) remove rotorcraft operations from active runways and allow aircraft and rotorcraft simultaneous non-interfering operations (SNIs). The procedures include point-in-space (PinS) and rely on required navigation performance (RNP 0.3). The rotorcraft capabilities of tight turns, steep climb and descent, combined with dedicated IFR procedures based on satellite and RNP navigation specification not only avoid the interaction of rotorcraft with fixed-wing aircraft, but also optimise operations in obstacle-rich urban environments and noise sensitive areas. The solution targets in particular relatively large and very large airports and high complexity terminal airspaces.

SESAR JU partners developed and assessed independent departure and approach PinS procedures in Milan Malpensa and Zurich airport environments. Simulation exercises were followed by live flight trials using helicopters equipped with automatic dependent surveillance – broadcast (ADS-B) out capabilities and included testing contingency events.

The validation exercises demonstrated reduced workload for controllers and pilots, improved rotorcraft access to busy airports and reduced fuel consumption. Implementation costs are also minimal as no specific ground infrastructure is required. The solution also confirmed that the new procedures can be flown with optional technical enablers related to synthetic vision systems and GBAS.

Industrialisation and deployment requires further evaluation of aspects including controller/pilot workload during non-nominal events, training and local safety case development.

Existing European and international standards are already compatible with the implementation of the operational solution, which has been implemented in Austria and Estonia.

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BENEFITS

- Improved access and equity
- Improved efficiency at busy airports
- More predictable operations for all users
- Greater flexibility and enhanced safety

ICAO PBN concept is fully integrated into EASA regulatory frameworks

ICAO PBN manual DOC9613, 4th Edition, describes RNP0.3 navigation specification





Advanced air traffic services

The future European ATM system will be characterised by advanced service provision, underpinned by the development of automation tools to support controllers in routine tasks. The feature reflects this move towards further automation with activities addressing enhanced arrivals and departures, separation management, enhanced air and ground safety nets and trajectory and performance-based free routing. The increased use of digital connectivity enables increased virtualisation of service provision, opening up more options for ATM service delivery.



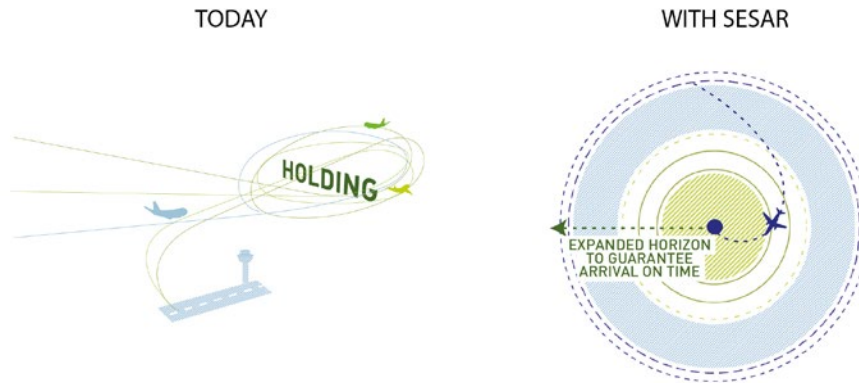


SJU references:
#05/Release 4

ASSIGNING HOLDING STACKS TO HISTORY

Extended arrival management (AMAN) horizon

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BENEFITS

- Improved operational efficiency by reducing holding times
- Improved operational efficiency by reducing fuel burn and emissions
- Efficiency in terms of air navigation service provision
- Improved safety and quality of service

Today, arriving traffic is managed and sequenced in the airspace close to the airport. Faced with increasing traffic, airports are looking for ways to overcome congestion and reduce the need for holding. Planning arrivals into a busy airport an hour or more before touchdown cuts down holding time, reduces noise and saves fuel.

Extended-AMAN (E-AMAN) allows for the sequencing of arrival traffic much earlier than is currently the case, by extending the AMAN horizon from the airspace close to the airport to further upstream and so allowing more smooth traffic management. Controllers in the upstream sectors, which may be in a different control centre or even a different functional airspace block (FAB), obtain system advisories to support an earlier pre-sequencing of aircraft. Controllers implement those advisories by, for example, instructing pilots to adjust the aircraft speed along the descent or even before top-of-descent, thus reducing the need for holding and decreasing fuel consumption.

E-AMAN is supported by sharing the airport's arrival management information with upstream sectors in real time. All parties share the same information using a system-wide information management (SWIM) service.

SESAR partners have shown that E-AMAN can be extended up to 200 nautical miles (NM) from the airport.

This solution is available for industrialisation. Already used at London Heathrow and London Gatwick, the solution is part of synchronised deployment plans across Europe.

Heathrow has saved the airlines 8kt of fuel and reduced CO₂ emissions by 25kt by transferring 120k minutes of holding delay from the TMA to the en-route and descent phases each year. Gatwick is expected to save more than 26k minutes every year in airborne low-level holding, saving the airlines around 1.2kt of fuel and reducing CO₂ emissions by 3.8kt





IMPROVING ARRIVAL EFFICIENCY AND PREDICTABILITY

SJU references:
#107/Release 2

Point merge in complex terminal airspace



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The point merge route structure provides a more efficient way to vector aircraft down to the final approach path. It allows departure and arrival streams to operate independently without risk of conflict, and delivers more predictable arrival times. The concept is simple. By designing standard sequencing legs ahead of the final approach point, aircraft can be guided along shorter or longer distances in order to reach a single entry point. For a busy terminal area controllers can start to sequence arrivals at an earlier stage, while pilots receive fewer interventions so can fly a more efficient approach path down to the runway.

BENEFITS

- Increased capacity in the terminal airspace
- Improved safety levels
- Improved air navigation service provision
- Reduced fuel consumption and emissions

At the extremity of the terminal airspace, arriving aircraft are vectored along an arc from where the timing of their turn towards the merge point determines the landing sequence. The procedure takes advantage of precision navigation technology (P-RNAV) on board modern aircraft, enabling them to fly precise pathways in the sky. The simplicity of point merge means that it is intuitive for the controllers to use, and requires fewer radio exchanges with the pilot. Fewer radar vectors also means less uncertainty on the flight deck with regard to the anticipated tactical route and the distance to go. The pilot can fly a continuous descent approach (CDA) path - rather than stepped height changes - consuming less fuel, while non P-RNAV equipped aircraft can still be vectored to the final approach point.

Point merge systems provide a high degree of structure and standardisation, which can be applied to multiple airports

Live trials have demonstrated the potential to increase airspace capacity in more complex environments, while maintaining or improving safety, air navigation provision efficiency and reducing emissions.

Point merge requires no changes on board the aircraft, however does require redesign of the terminal airspace

This solution is available for industrialisation. SESAR validation activities successfully demonstrated the application of point merge procedures in complex TMAs. Point merge is already providing more efficient arrival streams into Ireland (Dublin), Italy (Milan Bergamo), Spain (Gran Canaria) and the UK (London City and Biggin Hill).





SJU references:
#108/Release 2

ELIMINATING HOLDING PATTERNS IN THE EXTENDED TERMINAL AREA

Arrival management (AMAN) and point merge

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BENEFITS

- Better management of human resources
- Improved pilot situational awareness through the application of more standardised procedures
- Enhanced safety
- Reduced noise impact

Point merge not only delivers a more efficient arrival route structure in the terminal airspace, it can be applied to the extended terminal airspace area for pre-sequencing traffic. SESAR has developed point merge for this environment to enable the arrival manager (AMAN) to establish a more predictable arrival sequence. Integrating and optimising arrival streams contributes to the overall arrival management process both in terms of aircraft efficiency and airport operations. It is this predictability which can significantly improve capacity in dense and complex terminal airspace, and avoid unnecessary holding.

The solution is composed of a point merge system coupled with an arrival management tool that provides sequencing support based on trajectory prediction. Rather than entering holding patterns, aircraft in the extended terminal area enter PBN routes referred to as point merge legs, where they fly briefly in a level-off lateral holding situation where the distance to the merge point remains constant. When the spacing with the preceding aircraft is attained, the controller will instruct the next aircraft on the leg to turn direct to the merge point. Unlike conventional traffic streams which are individually vectored, the turn the aircraft needs to perform in the point merge leg is always the same, which simplifies the controller's tasks. The flight crew's task is also simplified by the use of this standardised manoeuvre which is predictable and repeatable.

Flight trials have demonstrated the workability of the concept. Controllers commented on the reduction in radio communications and experienced a more orderly traffic flow. There was better adherence to AMAN advisories before aircraft reached terminal airspace, and delays tended to be absorbed in the extended terminal area, reducing noise emissions at lower altitudes.

Airspace users have the opportunity to fly continuous descent operations from the point merge legs to the merge point. The point merge legs can be flown with different PBN capabilities, which allows a mixed navigation capability to operate within the same airspace.

This solution is implemented in France (Paris Charles de Gaulle).

Point merge is one of the ICAO Aviation System Block Upgrades and is referenced as a technique to support continuous descent operations

Applicable for terminal airspace handling over 100 hourly movements and en-route airspace handling over 300 hourly movements during peak hours

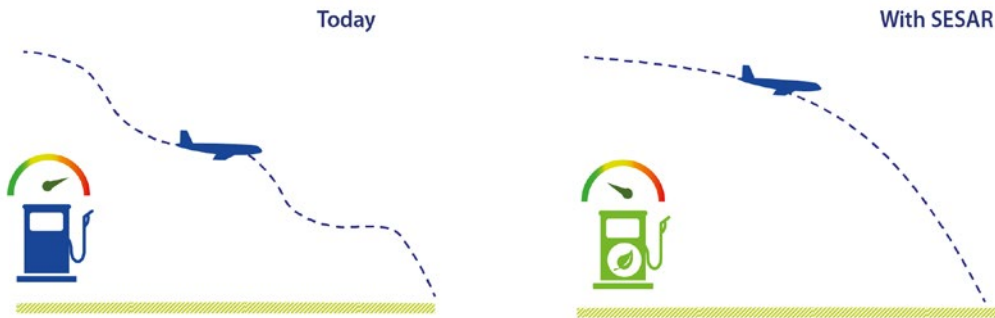




SMOOTHER, QUIETER, AND MORE EFFICIENT

Continuous descent operations (CDO) using point merge

SJU references:
#11/Release 5



STAKEHOLDERS
ANSP
AO
AU
NM

Aircraft engines have become quieter but an aircraft's flight path can also help reduce noise levels by following a smooth descent down to the runway threshold rather than a conventional stepped approach. Up until now, these continuous descent operations (CDOs) have been restricted to low and medium traffic density environments due to their impact on airport capacity. By combining it with point merge techniques, SESAR has extended the solution so it can be applied to high-density traffic environments at a lower altitude and in a small and very constrained airspace.

BENEFITS

- Reduced fuel burn and emissions
- Reduced environmental impact of airports on their neighbouring communities
- Noise reduction

During the validation of the solution, aircraft were vectored to a common merge point from where they followed a single air navigation trajectory (RNAV) procedure to intercept the instrument landing system (ILS). Since all sequencing procedures were completed by the merge point, from there pilots could follow an unconstrained descent path. In this procedure, controllers do not need to issue any level-off clearances after the merge point, while fewer level-offs are required earlier during the vectoring to merge point procedure. This results in higher profiles in the vicinity of the airport.

Making CDOs possible in complex airspace

Results showed that noise levels for inhabitants living near the airport were reduced with the introduction of the vector to point merge procedure. The solution also allows better control of the geographical area impacted by the noise using the RNAV trajectory capabilities, which allows the concentration or dispersion of traffic depending on the characteristics of the local area. This data is collected using a series of noise stations placed under the arrival paths to test the noise impact of the traffic before and after the flight trials.

Simulations and live flight trials allowed aircraft to fly higher approach paths resulting in less noise impact and lower emissions in the vicinity of the airport

This solution is implemented in Austria, France (Paris Charles de Gaulle) and the UK.

This solution is linked to the ICAO PBN Manual (Doc 9613), EUROCAE ILS standards and ICAO's PANS OPS (8168), as well as various avionics sensor standards



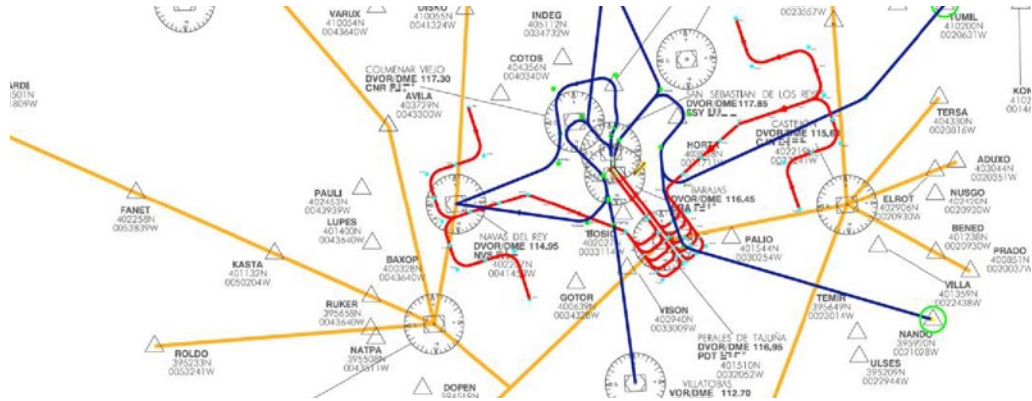


SJU references:
#62/Release 1

FLYING MORE EFFICIENT ROUTES

Precision area navigation (P-RNAV) in a complex terminal airspace

STAKEHOLDERS
ANSP
AO
AU
NM



BENEFITS

- Enhanced safety thanks to better precision
- Reduced fuel burn and emissions
- Improved air navigation service provision

Equipped to fly to within an accuracy of one nautical mile (NM), modern aircraft have the capability to follow very flexible routes, for example reducing noise impact on populated areas and easing bottlenecks. This navigation capability is especially useful in busy terminal airspace, where the increased accuracy allows more approach paths, which can release capacity, reduce holding and cut emissions.

Introducing precision area navigation (P-RNAV) procedures improves the design and organisation of the airspace allowing the aircraft's on-board navigation system to fly optimised flight paths.

P-RNAV supports more efficient continuous descent approaches and continuous climb departures in place of traditional stepped flight profiles issued by a controller. P-RNAV also supports curved approach paths which can avoid complex interaction between inbound and outbound traffic, heavily populated areas, and can reduce track miles for inbound aircraft.

SESAR partners carried out real-time simulations of P-RNAV implementation, where the new approach paths were introduced to reduce congestion experienced with existing arrival streams. P-RNAV procedures were integrated with conventional routes, resulting in a reduction of airborne holding time enabled by the path-stretching possibilities offered by the new route structure.

The validation site used is representative of many high-density terminal airspace encountered elsewhere in Europe, where the introduction of P-RNAV procedures offer the possibility of reducing fuel consumption and environmental impact as a result of the increased flexibility in airspace design, which allows strategic de-confliction of routes that enable better climb and descent profiles.

The solution is implemented in 13 countries in Europe.

P-RNAV procedures can deliver reductions in fuel burn and emissions as they allow increased possibilities for strategic route de-confliction, which enable smooth, low fuel consumption continuous descent and climb operations





DESIGNING MORE EFFICIENT AIRSPACE

Optimised route network using advanced required navigation performance (RNP)

SJU references:
#10/Release 5



New possibilities in advanced airspace design solutions and options are now possible thanks to the precision in airborne navigation using the improved navigation performance provided by required navigation performance (RNP) on board modern aircraft. This solution supports connectivity between free route airspace and TMA's thanks to advanced RNP below flight level 310.

Aircraft with RNP specifications are equipped with on-board performance monitoring and alerting to continually check conformance. Aircraft flying advanced A-RNP procedures can be relied on to stay within one mile on either side of the nominal flight path whether flying a straight leg or a turn. In practical terms, this means that controllers can have greater confidence in the track-keeping performance of the aircraft and this greater confidence translates into being able to place routes closer together. Nominal RNP1 routes can be designed as close as seven nautical miles (NM) in en-route sectors and as close as five NM in terminal airspace. Advanced RNP (A-RNP) routes support precise flight profiles such as spaced parallel routes, fixed radius transition (FRT) and tactical parallel offset (TPO).

One of the main benefits provided by A-RNP is the potential to increase the overall efficiency of the air traffic management system, as a result of the greater flexibility of airspace design. This allows, for example, being able to place flight paths, arrival and departure routes, in the most convenient place. The predictable turn performance inherent in A-RNP in en-route and terminal airspace also makes it possible - due to enhanced track keeping in the turn - to place routes where they cannot necessarily be placed today using less advanced navigation capabilities.

A-RNP with on-board performance monitoring results in more predictable aircraft behaviour

This solution is linked to ICAO's performance-based navigation (PBN) manual (Doc 9613)

This solution is available for industrialisation and has been implemented in Italy.

STAKEHOLDERS

- ANSP
- AO
- AU
- NM

BENEFITS

- Enhanced safety
- Improved operational efficiency by reducing fuel burn and emissions
- Improved air navigation service provision





SJU references:
#09/Release 5

FLEXIBLE ARRIVALS AND DEPARTURES

Enhanced terminal operations with RNP transition to ILS/GLS

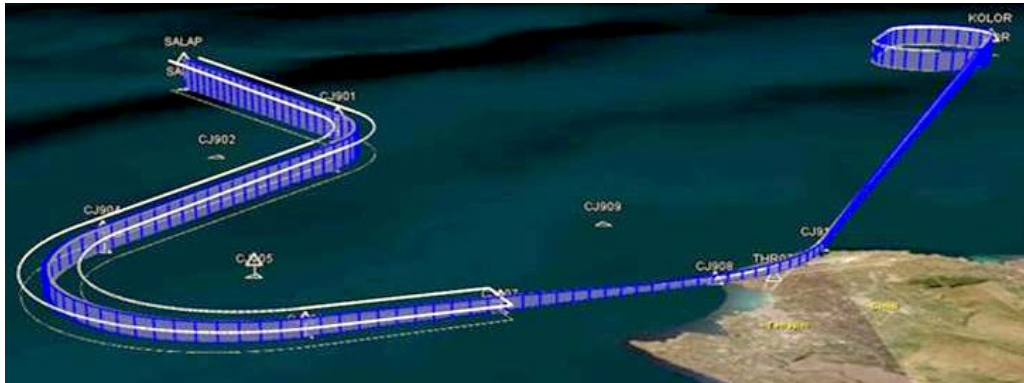
STAKEHOLDERS

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BENEFITS

- Improved fuel efficiency
- Increased runway throughput (GBAS)
- Enhanced safety

The focus on efficient, green operations at European airports has led to the development of more flexible arrival and departure routes which take advantage of the satellite-based navigation capability on board modern aircraft. This solution refers to the use of curved procedures enabled by advanced required navigation performance (RNP) with a transition to ILS/GLS. This allows aircraft to follow new approach paths, for example to avoid noise emissions over populated areas, reduce track miles, and add new flight paths, while also achieving ILS landing guidance to low-minima of 200 ft and below.

Modern flight management systems have the ability to fly a repeatable curved trajectory, known as radius-to-fix (RF), which some airports are adding to their arrival and departure procedures. SESAR has worked on the introduction of these turns by supporting the design of new procedures that connect the route structure to the final approach path. Final approach guidance may be provided by existing ILS, but for GBAS-equipped airports they may also be provided by new ground-based augmentation system (GBAS) landing systems (GLS), using constellations such as Galileo.

Flight trials were carried out to validate new arrival procedures based on the use of different glide path angles for two arriving aircraft aiming at different touchdown zones on the runway to reduce the risk of wake encounter. The exercise sets out to confirm the operational feasibility of the procedure, including its impact on the situational awareness of controllers and pilots.

This solution is available for industrialisation and is implemented in Cyprus, Malta, Montenegro and Slovakia.

Advanced RNP procedures improve access to busy airports, help to maintain all-weather operations, and reduce environmental impact

This solution is linked to ICAO's performance-based navigation (PBN) manual (Doc 9613)





TRANSITIONING TO FINAL APPROACH

Enhanced terminal operations with RNP transition to LPV

SJU references:
#51/Release 4



- STAKEHOLDERS
- ANSP
- AO
- AU
- NM

Satellite-based navigation systems, including Galileo, enable aircraft to follow precise flight paths independently of ground-based infrastructure. The technology supports additional approach paths without the need to add instrument landing systems (ILS), and can be used as part of a fall-back procedure in case of airborne or ground ILS equipment malfunction.

This SESAR solution defines required navigation performance (RNP) transitions to localiser performance with vertical guidance (LPV) to enhance terminal operations. SESAR supports wider use of advanced RNP to enhance terminal area operations. SESAR's advanced approach procedures with vertical guidance (APV) include the smooth transition from RNP arrival routes into RNP approach flight paths with barometric descent guidance that then transition to the LPV approach segment with geometric descent guidance. The transitions may include radius-to-fix (RF) turns that leave the aircraft aligned with the runway as close as three nautical miles (NM) before the threshold. From that point, the satellite-based guidance allows the pilot to descend safely down to a decision height of 200 ft which is equivalent to ILS Cat I minima. Advanced APV allows increased flexibility in planning arrival paths in terminal airspace, making it possible to design procedures that control the noise impact of the airport or reduce track miles to cut fuel consumption.

Several validation exercises focused on preparing ways to introduce A-RNP transition to LPV procedures by examining the impact on both the ground and air segments. The new transitions increased predictability for controllers and pilots, while reducing track miles, saving fuel and emissions.

This solution is linked to ICAO's performance-based navigation (PBN) manual (Doc 9613)

This solution is available for industrialisation. Enhanced terminal operations with LPV procedures are now implemented in implemented in Cyprus, Malta, Montenegro and Slovakia.

- BENEFITS
- Increased flexibility in the design of TMA route layouts and landing procedures, which result in fuel savings and reduced noise impact on the communities neighbouring the airport
- Increased predictability
- Improved safety



SJU references:
#103/Release 1

PREPARING TO LAND

Approach procedures with vertical guidance

STAKEHOLDERS

ANSP

AO

AU

NM



BENEFITS

- **Improved access to airports in all weather conditions, without the need to install ground equipment**
- **Improved descent profile and reduced track miles, resulting in reduced fuel burn**
- **Reduced noise footprint**
- **Improved safety**

Satellite-based technology, supported by constellations such as Galileo, provides approach guidance without the need for ground-based navigational aids, increasing accessibility and safety at many airports. An aircraft can fly instrument approaches similar to a conventional instrument landing system (ILS) - down to a 200ft decision height. A localiser performance with vertical guidance (LPV) approach uses global navigation satellite system (GNSS) signals augmented by the European geostationary navigation overlay service (EGNOS), the three-satellite constellation that improves the precision of GNSS in the European area and was certified for safety of life (SoL) service in 2011.

LPV procedures do not require any new equipment at the airport which makes them an ideal low-cost alternative to increase access to secondary airports that may not be ILS-equipped on all runways. For ILS-equipped runways, the new approach design may be useful either to shorten the flightpath for certain traffic flows or simply to overlay the existing ILS and be used as a fall-back procedure in case of airborne or ground ILS equipment malfunction.

SESAR validation activities demonstrated that LPV approaches can be safely integrated into the operational environment. The exercises showed that the implementation of LPV procedures allowed aircraft coming from a downwind inbound route saved track miles compared to the traditional ILS approach. Moreover, in low traffic conditions controllers were able to safely integrate LPV aircraft flying short downwind approaches with ILS aircraft flying longer downwind approaches while allowing the LPV aircraft to execute the LPV descent profile. Using satellite-based technology also means avoiding costs associated with airport closure or flight diversions due to bad weather conditions. The exercises provided valuable lessons learnt for the design of LPV procedures, such as the importance of defining and using standard phraseology.

The solution is available for industrialisation and is implemented in Armenia, Croatia, Czech Republic, Hungary, Malta, Montenegro, Luxembourg and Poland.

ICAO supports integration of satellite-based navigation with vertical guidance into the airspace environment

Airport landing rate can be maintained with LPV procedures





ENABLING ROTORCRAFT OPERATIONS IN BUSY AIRSPACE SURROUNDING AIRPORTS

SJU references:
#113/Release 5

Optimised low-level instrument flight rules (IFR) routes for rotorcraft



STAKEHOLDERS
ANSP
AO
AU
NM

Due to their different operational characteristics to fixed-wing aircraft, especially their lower speed and vulnerability to bad weather, rotorcraft operations inside controlled airspace and terminal manoeuvring areas (TMA) are often limited to visual flight rules (VFR) flights in visual meteorological conditions (VMC). Flights under instrument flight rules (IFR) are often severely constrained or even prohibited altogether. The introduction of IFR procedures specifically designed for rotorcraft enables their safe integration into controlled airspace without adversely affecting existing fixed-wing operations.

BENEFITS

- Increases access to TMAs for rotorcraft
- Increases safety and resilience of rotorcraft operations
- Reduced noise

This SESAR Solution enables the design of IFR routes at very low level, based on the ability of suitably-equipped rotorcraft to navigate very accurately using global navigation satellite systems (GNSS) using the European satellite-based augmentation system (SBAS): the European Geostationary Navigation Overlay Service (EGNOS). Routes are designed to an enhanced required navigation performance (RNP) standard that allows an optimised use of the airspace within medium and dense/complex TMAs. Routes are designed to either RNP 1 or RNP 0.3 depending on the altitude and degree of precision needed as a result of neighbouring procedures, airspace and/or terrain.

Dedicated low-level IFR routes for rotorcraft not only improve safety, equity and accessibility in the airspace inside the TMA, but may also increase TMA capacity

This solution is linked to the ICAO PBN Manual (Doc 9613) and PANS OPS (8168), as well as various avionics sensor standards

Provision of the IFR routes in controlled airspace procedurally separates rotorcraft and fixed-wing traffic. The integration of an optimised low-level IFR route network for rotorcraft can enhance flight safety and weather resilience of rotorcraft operations. Benefits for the environment may also be expected due to fewer VFR flights at very low altitude and avoidance of noise-sensitive areas thanks to narrow and/or curved low-level procedures.

These low-level IFR routes can be directly linked to dedicated point-in-space (PinS) arrival and departure procedures, where published, enabling simultaneous non-interfering (SNI) operations that are procedurally segregated from conventional fixed-wing operations. The solution is implemented in Norway and Switzerland.





SJU references:
#PJ.01-06/
Release 9

ROTORCRAFT USING POINT-IN-SPACE NAVIGATION FLY SAFER ROUTES

Enhanced rotorcraft operations in the TMA

STAKEHOLDERS

ANSP

AO

AU

NM



BENEFITS

- Improved pilot situational awareness
- Enhanced safety
- Reduced fuel burn
- Improved access and equity for rotorcraft users

Helicopters frequently operate in difficult terrain and at different speeds to other airspace users. Procedures to help pilots navigate more accurately improve safety by reducing workload and providing more flexibility. By introducing advanced approach and departure procedures in the terminal manoeuvring area (TMA), SESAR demonstrates how point-in-space (PinS) approaches based on augmented GNSS signals result in more flexible approach paths, including curved approach segments. Pilots benefit from easier access to final approach and take-off points while reducing the potential impact on other airspace users. The approach and departure paths can connect with the low-level instrument flight rules (IFR) route network, if present, and can include curved procedures in the initial, intermediate, final and missed approach segments.

The solution also contributes to reduced noise footprint and improved access to final approach and take-off points with vertical guidance. This is in addition to the safety benefits of reducing the use of visual flight rules (VFR) in marginal conditions, particularly low-visibility.

SESAR partners carried out three validation exercises including a real-time validation followed by flight trials at an airport and heliport in VFR and IFR conditions. An optional head-mounted display was also used by pilots and this further improved situational awareness. The scenarios included assessment of the navigation performance, human factors and crew workload. Using PinS approaches enabled the helicopters to fly with greater accuracy and more flexibility in dense and constrained airspace and resulted in low crew workload during the RF segments.

The findings recommend introducing rules to promote IFR operations for helicopters, along with exploration of alternative satellite navigation services in the event of GNSS loss or jamming.

The solution is available for industrialisation.

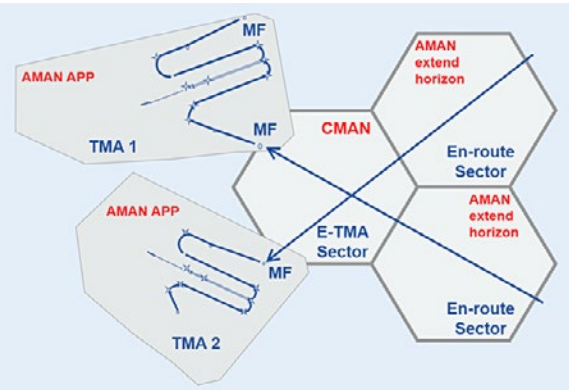
This operational improvement builds on already mature SESAR 1 standard PinS by adding more advanced procedures, such as curved approaches. It enables pilots to fully utilise rotorcraft performance while reducing fuel use and noise emissions. The head-mounted display further enhances safety by increasing situational awareness. The solution is applicable to IFR certified rotorcraft with advanced navigation performance capability, has no impact on ground infrastructure and conforms with ICAO procedures for air navigation services.



STREAMLINING TRAFFIC FLOW INTO MULTIPLE AIRPORTS

SJU references:
#08/Release 5

Arrival management into multiple airports



STAKEHOLDERS
ANSP
AO
AU
NM

Some airports in Europe are located very close to one another, which means that they must share the surrounding airspace, or terminal manoeuvring area. However, in today's air traffic management, airports are considered as separate entities rather than integrated nodes in a wider network. As a result, aircraft cannot always access the most efficient routes in terminal airspace.

BENEFITS

- Enhanced predictability
- Improved fuel efficiency
- Better use of available capacity
- Enhanced safety

This SESAR solution coordinates traffic flows into multiple airports by means of a centre manager (CMAN). The solution operates in conjunction with the arrival management systems of the different airports to develop optimum arrival streams, based on balancing the demand and capacity. The CMAN uses airport data including predicted departure times and the extended arrival management horizon in order to calculate the most efficient arrival streams.

This solution looks at converging arrival streams, and spacing the aircraft to optimise traffic flow in order to reduce the need for tactical interventions by controllers. By imposing a time-to-lose (TTL) constraint, aircraft can be sequenced efficiently in the extended terminal area, reducing the need for subsequent radar-vectoring. The aim is to establish a new multi-airport arrivals concept that is expected to increase air navigation service efficiency, in particular the use of tactical voice communications, and deliver more fuel-efficient arrival streams.

The solution offers the most benefit in more complicated terminal airspace, where airports already use arrival management tools to smooth queues. A series of real-time simulations looked at converging arrival streams, spacing aircraft to optimise traffic flow in order to reduce the need for tactical interventions by controllers. The validation exercises also assess training and staffing requirements.

More predictable arrival streams reduce the need for tactical interventions by controllers

CMAN helps to adjust capacity to match predicted demand in a complex terminal environment serving multiple airports

This SESAR Solution is available for industrialisation and has been implemented in Germany (Cologne Bonn and Dusseldorf).





SJU references:
#06/Release 5

AIRBORNE SELF MANAGEMENT FOR MORE PRECISELY TIMED ARRIVALS

Controlled time of arrival (CTA) in medium-density/medium-complexity environments

- STAKEHOLDERS
- ANSP
- AO
- AU
- NM



BENEFITS

- Improved fuel efficiency per CTA flight
- Enhanced predictability
- Improved flight crew situational awareness

Building an arrival sequence in medium- and high-density environments calls on controller resources from an early phase in the approach procedure. The process is predominantly ground-based and can result in late vectoring and unnecessary holding rather than fuel-efficient strategies based on en-route speed management for efficient delay absorption. By combining time management capabilities on board aircraft with ground-based system support, the arrival management process can be more predictable and deliver more efficient operations.

Controlled time of arrival (CTA) is a time constraint defined by air traffic control that allows an aircraft to self-manage its speed in order to arrive at a specific time at a defined point associated with an arrival runway. The controller calculates the CTA as part of the arrival management process and relays this information to aircraft equipped with this advanced navigation capability. While arrival management systems are not able to evaluate the most fuel-efficient strategy for each individual aircraft, each aircraft's flight management system will optimise the flight speed according to aircraft type and wind conditions.

More inclusive use of airborne technologies provides better investment return for airspace users on equipment that many have already installed in their aircraft

SESAR validated how CTA operations can be applied in medium-density and complex terminal airspace. Many aircraft are already equipped with flight management systems that support flying to a time constraint through the use of the required time of arrival (RTA) airborne function.

This SESAR Solution is available for industrialisation and has been implemented in Austria.





SUPPORTING TEAM WORK

Sector team operations - en-route air traffic organiser

SJU references:
#104/Release 1



The sustained traffic growth in the 1980s prompted the launch of the en-route air traffic organiser concept, to design electronic decision-making tools to help controllers. It recognised that there was a need to optimise service provision by assisting with detecting and monitoring tasks, freeing up mental resources to focus on resolving conflicts between flights.

In this framework, the SESAR solution is a medium-term conflict detection (MTCD) tool that allows controllers to filter aircraft and extrapolate their future positions. The tool is based on providing assistance to controllers particularly when faced with stress, fatigue or other disturbing agents. The solution does a number of things to help the controller. It shades out – according to pre-determined criteria – flights which are not relevant to a particular situation. It provides visual aids to help the controller schedule tasks. It also extrapolates the predicted trajectory of specific flights to aid the controller to identify potential conflicts well in advance. In addition, it provides geographical markers to provide the controller with task reminders at specific locations.

The solution allows controllers to perform control tasks more effectively using the support tools and working methods. The solution can bring benefits to any busy en-route environment.

This solution is ready for industrialisation and is now implemented in 23 countries across Europe.

The SESAR tool improves information and task sharing, and enhances cooperation between planner and executive controllers

SESAR validation results demonstrated a real potential for increasing the effectiveness of controllers in performing their tasks

STAKEHOLDERS

ANSP

AO

AU

NM

BENEFITS

- Effective management of team operations
- Improved monitoring of traffic as well as information and task sharing
- Increased en-route airspace capacity

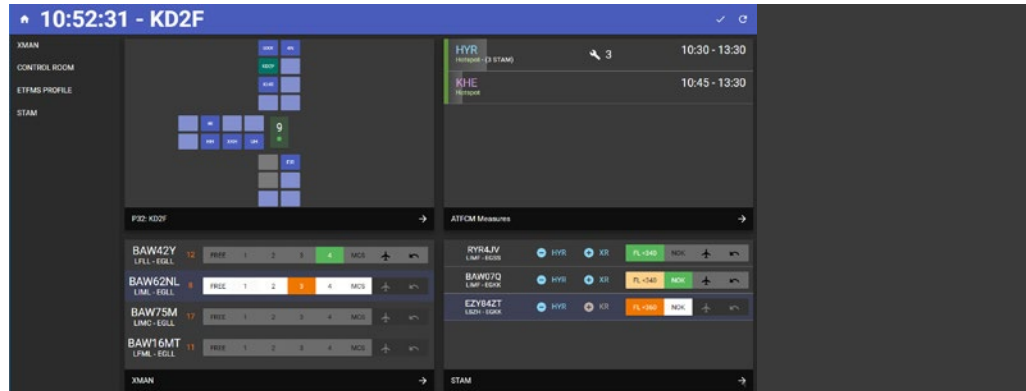
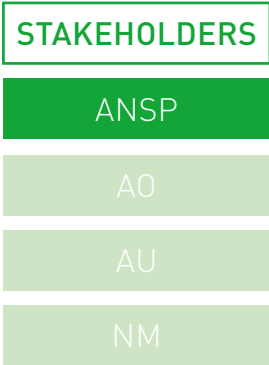




SJU references:
#118/Release 7

HANDLING COMPLEXITY IN THE SKY THROUGH AUTOMATION

Basic extended ATC planning (bEAP)



BENEFITS

- Improved operational and cost efficiency
- Enhanced levels of safety

Basic extended ATC planning is an automation tool and a set of procedures that support controllers in managing highly complex traffic. The solution aims to bridge the gap between air traffic flow and capacity management (ATFCM) and air traffic control. It provides real-time and fine-tuned measures to solve ATFCM hotspots, enabling early measures to be taken by ATC before traffic enters in overloaded sectors.

The solution introduces an initial automated interface together with the related procedures that will facilitate the communication between local demand-capacity balancing (DCB) position and the controllers' working positions. The main benefits of the EAP function are better service provision to airspace users through reduced delays, better punctuality, less ATFCM regulations, and enhanced safety. The solution is seen as a potential enabler for the deployment of solutions, such as extended AMAN or free routing operations. Following validations in 2015/2016, the solution was approved by French national supervisory authority (NSA) in December 2016 and has since been deployed by DSNA and has become operational at Reims, Bordeaux and Brest ACCs.

This SESAR solution is ready for industrialisation and has been implemented in France and Switzerland.





USING CONTROLLER RESOURCES EFFECTIVELY

Multi-sector planning

SJU references:
#63/Release 2



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

Advanced controller tools present an opportunity to look at managing the resources of the air traffic control workforce in new ways, especially when it comes to planning and pre-tactical tasks. With access to electronic flight data, decision-making tools such as what-if or look-see functions, the role of the planning controller has become more flexible. SESAR's multi-sector planning solution reconsiders the usual air traffic control team – composed of a planner for each tactical controller – and proposes a structure whereby a planner can support two tactical controllers, each responsible for a different sector.

BENEFITS

- Improved task sharing
- Better distribution of human resources
- Improved cost efficiency due to flexibility in sourcing and deployment of human resources

The new operating procedures are a direct result of enhancements to the planning tools, such as the aforementioned solution, which improve the efficiency of the planning and decision-making process. They are not expected to be applicable to all sectors at all traffic levels, but a number of sectors can be combined in this way and operate efficiently at reasonably high traffic levels.

Multi-sector planning improves efficiency and flexibility in manning air traffic control sectors while sectors are only split when required by the level of traffic

A further phase of solution development is extending the new team structure beyond one planner supporting two tactical controllers, to several tactical controllers under the responsibility of a single planner controller. This evolution will require developing the way in which boundaries are defined between planning and tactical control.

While the solution is not expected to be applicable to all sectors at all traffic levels, the SESAR validation exercises showed that a number of sectors can be combined in this way and operate efficiently at reasonably high traffic levels

The solution is available for industrialisation and is implemented in Italy, Malta, Norway, Poland, Romania and Sweden.





SJU references:
#PJ.10-01a1/
Release9

A NEW MULTI-SECTOR PLANNER POSITION IMPROVES TASK SHARING

High productivity controller team organisation in en-route (including eTMA)

STAKEHOLDERS

ANSP

AO

AU

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BENEFITS

- Improved operational and cost efficiency
- Maintained levels of safety
- Better use of human resources

Traditionally ATC operations are based on a team composed of two air traffic controllers, who undertake the roles of planning controller (PC) and executive controller (EC). As demands on European airspace are expected to grow, and new entrants such as unmanned and high-altitude aerial vehicles take to the skies, maintaining safe and efficient traffic flow stands to benefit from a combination of human intervention and automation tools.

Among new team structures, SESAR JU partners have developed a multi-sector planner position with responsibility for airspace controlled by up to two executive controllers (2ECs). The multi-sector planner is able to adjust sector boundaries so that workload is balanced between controllers to achieve an efficient and safe distribution of tasks for traffic and separation management across the whole team. Demand and capacity balancing are considered but the main objective is tactical provision of separation between aircraft. The solution proposes addition coordination tools between the teams including conflict detection and resolution, electronic coordination between sectors, and flight conformance monitoring and applies to high and medium complexity airspace in both the en-route and terminal area environment.

SESAR JU partners validated this solution through a series of activities, including a gaming exercise and real-time simulation completed in SESAR 1. As a result of using the multi-sector planner position, tests showed increased flight predictability and reduced fuel burn in the en-route and extended terminal manoeuvring area (eTMA). Better distribution of human resources and improved task sharing resulted in a reduction in total-man hours. The solution is not applicable to all sectors at all traffic levels, but a number of sectors can be combined in this way and operate efficiently at reasonably high traffic levels.

No changes in regulatory aspects or certification activities are foreseen, however as the solution deals with new automated tools, new procedures will have to be developed for degraded mode and failure in line with existing methods.

Re-organisation of controller teams prepares ATC for new entrants

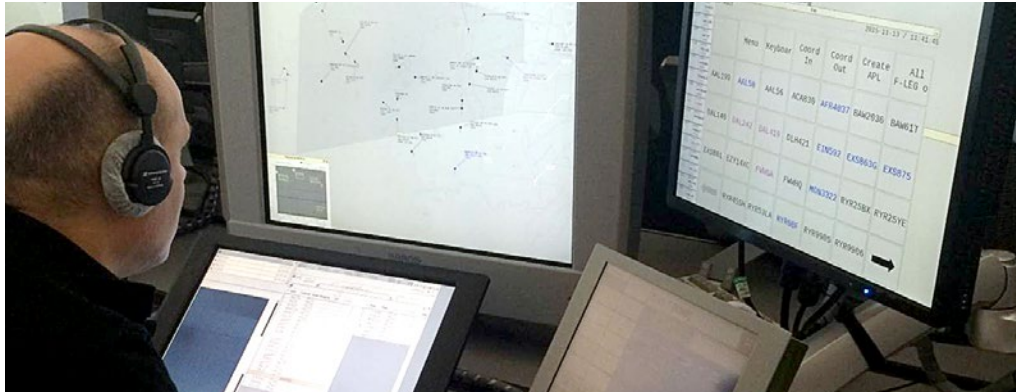
The solution is available for industrialisation and has been implemented partially in Ireland.



KEEPING AHEAD OF TRAFFIC WITH ADVANCED CONTROLLER TOOLS

Enhanced tactical conflict detection & resolution (CD&R) services and conformance monitoring tools for en-route

SJU references:
#27/Release 5



Providing controllers with improved coordination tools is key to meeting Single European Sky performance targets, which aim to triple airspace capacity. SESAR is supporting development of functions to aid capacity and safety.

Reliable and accurate conflict detection and resolution services lead to better decision making and fewer tactical interventions by controllers. This SESAR Solution consists of innovative approaches that provide the en-route controller with two separation provision services:

First, an enhanced monitoring conformance service (MONA) for both tactical and planning controllers. Compared to the existing MONA, this SESAR Solution includes a new alert to take into account lateral deviation and the rate change monitoring in climbing and descending phase to minimize false alerts.

Second, a conflict detection and resolution service fully dedicated and designed for the tactical controller with a conflict detection service down to flight level 100. This service is based on effective clearances and specific ergonomics and use developed for the tactical controller, but also available and usable for the planning controller

New conflict detection tools allow controllers to assess possible conflicts much sooner

Where existing tactical controller tools (FASTI baseline) do not fully match with the tactical controller's needs and do not cover all adherence deviations and present false alarms, this SESAR Solution can optimise air navigation service productivity, increases the benefits of such services, and increase the confidence of the en-route controllers in such coordination tools.

This Solution was validated through a series of exercises including several real-time simulations assessing the operational acceptability of automated tools in specific environments such as a free route environment.

Ultimately, the SESAR work focused on the distribution of tasks between planner and tactical controllers, and how the tools are integrated into the decision-making process.

This SESAR solution, which is available for industrialisation, is now implemented in 23 countries across Europe.

STAKEHOLDERS

ANSP

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AU

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BENEFITS

- Improved safety
- Optimised air navigation service provision
- Improved capacity
- Increased cost efficiency





SJU references:
#PJ.10-02a1/
Release 9

ENHANCED CONFLICT DETECTION AND RESOLUTION SUPPORT TOOLS EASE COMPLEX TRAFFIC MANAGEMENT TASKS

Improved performance in the provision of separation without use of ADS-C/EPP data

STAKEHOLDERS

ANSP

AO

AU

NM

BENEFITS

- Enhanced safety
- Optimised en-route and TMA capacity
- Enhanced predictability



The latest controller decision-support tools help to ensure safe separation between aircraft during en-route flight phases as well as in the terminal manoeuvring area. As a consequence, controllers rely on a high number of tactical interventions and use multiple radar vectors, stepped climbs and descents, in order to maintain separation between aircraft in high traffic situations. SESAR examined ways of delivering more accurate predictions of present and future aircraft positions through the use of aircraft-derived data, reducing the need for so many tactical interventions.

The solution aims at improving the tactical separation in the en-route and terminal area operational environments through improved ground trajectory prediction. This is achieved using existing information on lateral and vertical clearances that are known by the ground system and airborne information such as Mode S data.

The solution tested enhanced controller support tools and used extended air traffic planning procedures such as the multi sector planning position and extended ATC planning role described on the preceding page. Testing focused on tactical and planning controllers and included a fast-time simulation, several real-time simulations and a shadow mode trial.

The results showed improved situational awareness for controllers, better predictability and greater separation margins. The medium term conflict detection (MTCD) service, What-if and What-else services created an eco-system of ATC tools. When adapted to the free route high complexity environment, the addition of trajectory management tools, conflict detection and resolution tools, monitoring aids and electronic coordination all contributed to improved controller situational awareness. The What-else tool was especially important in high density traffic.

The increased level of automation suggested a potential increase in controller productivity. This was estimated at between 1.6% and 5.6% en-route, and 0.7% in the terminal manoeuvring area.

ANSPs also benefited from a capacity gain, estimated at around 4% on average, leading to an increase in cost efficiency. Estimated benefits reach more than 50% of the initial investment after just one year of operation. The solution is ready for industrialisation.

Controllers access improved support tools while airspace users and the Network Manager benefit from enhanced safety and efficiency



ALLOWING USERS TO CHOOSE THEIR ROUTE

User-preferred routing

SJU references:
#65/Release 2



Many aircraft currently follow fixed routes which are not always the most efficient in terms of time and fuel consumption. There are tactical refinements at an operational level, but SESAR is introducing far more radical change at a design level which ultimately aims to introduce free route airspace across Europe. This enables the operator's flight planning system to calculate the most efficient route taking into consideration wind speed and direction, turbulence, temperature, aircraft type and performance.

This solution is seen as an early iteration of the free route concept due to the potential for this option to mimic established direct route requests from operational airspace users. However, this solution does not take into account cross-border direct routing.

User-preferred routing validation is the result of a number of simulations and flight trials which thoroughly tested the procedures at night, on weekends and weekdays. The validation activities involved air traffic controllers, planners, and supervisors as well as aeronautical information services personnel. Several airlines also participated in the validation activities, learning how to operate the concept correctly, and how the routes are integrated into the wider network.

The results served to identify a list of direct routes within one air traffic service unit that could be implemented. They also showed the maturity of the solution which represents the first step towards the more advanced concept of free route operations.

The solution is available for industrialisation and is part of European synchronised deployment plans.

STAKEHOLDERS

ANSP

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BENEFITS

- Improved flight efficiency within one air traffic service unit
- Reduced average flown distance and reduced flight time
- Maintained air navigation service provision, despite capacity increase
- Reduced fuel burn and emissions
- Maintained levels of safety

User-preferred routing takes Europe a step closer to the concept of European free route airspace concept

This solution is linked to Eurocontrol specifications (STD 61/STD 62/STD 63/STD 64)



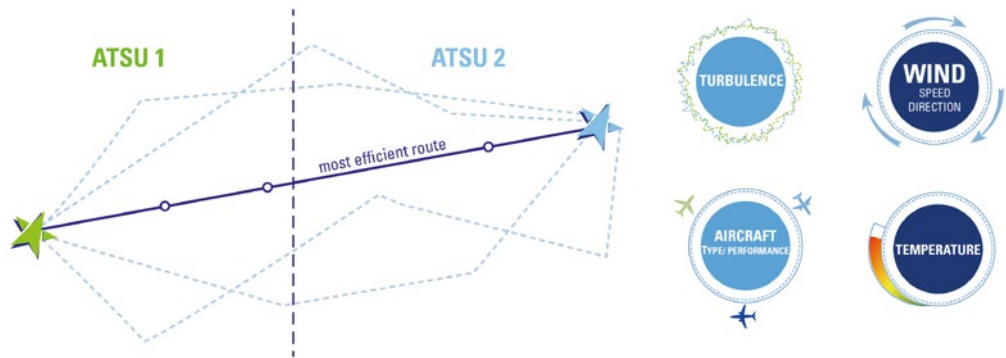


SJU references:
#32/Release 5

MORE DIRECT ROUTES FOR CROSS-BORDER OPERATIONS

Free route through the use of direct routing for flights both in cruise and vertically evolving in cross ACC/FIR borders and in high complexity environments

STAKEHOLDERS
ANSP
AO
AU
NM



BENEFITS

- Increased airspace capacity
- Improved operational efficiency
- Reduced fuel burn and emissions

Under the current network structure, aircraft fly an average of 20 km further than the most direct route between two points. This SESAR Solution represents a step forward with respect to the user-preferred routing solution. It offers more direct flight planning route options on a large scale, crossing flight information regions and national borders.

Direct routing allows airspace users the possibility to plan a route close to their preferred flight path by selecting a direct route - connecting published waypoints - without the need for the intermediate points to be present in the current fixed-route network.

The extension of direct routes across flight information regions and national boundaries require appropriate airspace changes, as well as new flight data processing systems from airspace users. Advanced flexible use of airspace at the regional scale supports the use of direct routing operations.

Published direct routes are established within local and regional documentation and then made available for flight planning. SESAR continues to support validation activities to assess the operational acceptability of cross-border direct routing operations.

The SESAR Solution is available for industrialisation and is being implemented across the whole of Europe's upper airspace as part of synchronised deployment.

Planned flight distances are reduced in comparison with the fixed route network and follow an optimised flight path

Direct routing is particularly relevant for cross-border operations in high and very high complexity environments

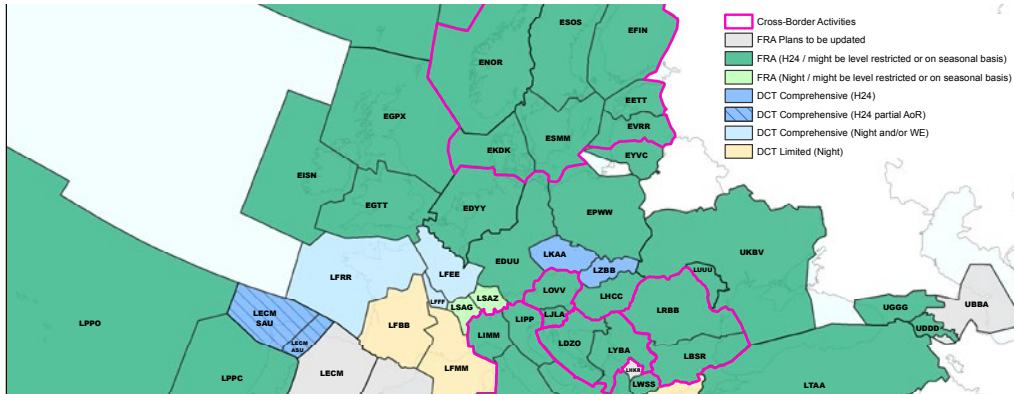




EUROPE-WIDE FREE ROUTING

Free route through the use of free routing for flights both in cruise and vertically evolving in cross ACC/FIR borders and within permanently low to medium complexity environments

SJU references:
#33/Release 5



- STAKEHOLDERS**
- ANSP
 - AO
 - AU
 - NM

Free routing corresponds to the ability of the airspace user to plan and re-plan a route according to the user-defined segments within free route airspace (FRA), where advanced flexible use of airspace (AFUA) principles provide the necessary airspace flexibility. This solution allows airspace users to plan flight trajectories without reference to a fixed route network or published direct routes within low- to medium-complexity environments.

The solution allows airspace users to plan trajectories, without reference to a fixed route or published direct route network. In doing so, it provides them with significant opportunities to optimise their respective flights in line with individual operator business needs and military requirements.

The validation activities for this solution included real-time simulations to assess the operational acceptability of free routing. The exercises compared service provision when dealing with free routing and direct routing traffic to assess what is required and acceptable and the likely benefits. The work also looked at airspace complexity and considered operational issues related to military airspace zones in a free routing environment.

The SESAR Solution is available for industrialisation and is part of Europe-wide synchronised deployment.

Flights benefit from optimised flight paths when planning flights using free routes, but remain subject to air traffic control during execution

SESAR exercises are reviewing a range of different flight levels for the introduction of free route airspace implementation

This solution is linked to Eurocontrol specifications (STD 61/STD 62/STD63/STD64)

BENEFITS

- Increased airspace capacity
- Improved operational efficiency
- Reduced fuel burn and emissions





SJU references:
#PJ.06-01/
Release 9

CROSS-BORDER FREE ROUTES IMPROVE PREDICTABILITY AND REDUCE FUEL CONSUMPTION

Optimised traffic management to enable free routing in high and very high complexity environment

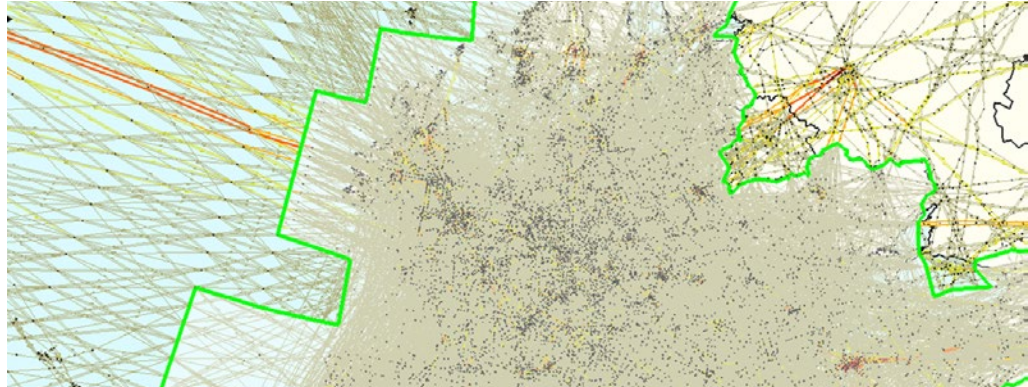
STAKEHOLDERS

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BENEFITS

- Optimised flight trajectories
- Reduced fuel consumption for airspace users
- Safety and capacity maintained

The free routing concept allows airspace users to plan flight trajectories without reference to a fixed route network so they can optimise their flights in line with their individual business needs. Building on previously research, this solution extends to cross-border operations and very high complexity upper airspace.

Rather than target unrestricted free routing operations, this solution focuses on the improvement of separation provision and aims at enabling safe and efficient operations with minimum structural limits. The solution also relies on the Network Management (NM) function to cope with any demand and capacity imbalances created from changes in dominant traffic flows in free route airspace through the monitoring of the traffic complexity levels together with the level of the traffic demand.

SESAR validated two applications using real-time simulations combined with an upgraded flight data processing system and enhanced controller tools to support conflict detection and resolution. The objective was to assess the impact of the solution on fuel efficiency and predictability and confirm the absence of any negative impact on safety and capacity. Human Performance aspects were also assessed.

Airspace users gain maximum benefit when free routing is supported by appropriate cross-border airspace design. This recommendation goes along with the outcomes of the Airspace Architecture Study, which highlights the importance of “an optimal flow centric redesign of airspace sectors” as a support for “a seamless free route airspace for the whole ECAC region”.

The solution is available for industrialisation and is part of Europe-wide synchronised deployment.

The validation exercises results show that the implementation of structurally limited cross-border free routing in high and very high complexity environment has no negative impact on controllers’ performance when assisted by appropriate ATC support tools. Airspace safety and capacity is also maintained. The environmental benefits are significant, with an estimated reduction in average fuel burn per flight of 26,57 kg within the 2035 timeframe.

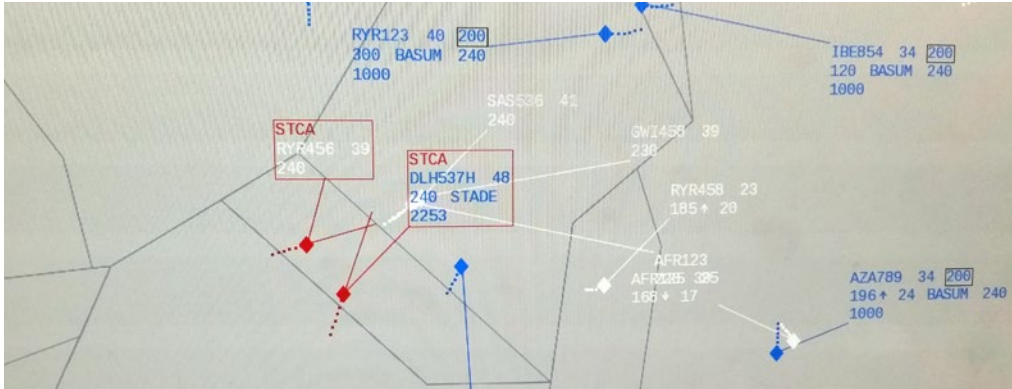




IMPROVING CONFLICT ALERT FOR CONTROLLERS

Enhanced short-term conflict alert (STCA) for terminal manoeuvring areas (TMAs)

SJU references:
#60/Release 1



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

Ground-based safety nets are an integral part of the ATM system. Using primarily ATS surveillance data, they provide warning times of up to two minutes. Upon receiving an alert, air traffic controllers are expected to immediately assess the situation and take appropriate action. A valuable safety net is the automated short-term conflict alert (STCA), a sophisticated algorithm which uses the track data to warn against possible short-term conflicts.

STCAs are challenging to develop since they must minimise false alerts, while at the same time making sure that real conflicts trigger an appropriate and timely warning. Specific tuning is necessary for STCA to be effective especially in the terminal airspace in order to account for lower separation minima, as well as increased frequency of turns, climbs and descents.

Validation exercises looked at enhanced STCA solutions to reduce the number of false and nuisance alerts compared to existing technologies, while maintaining the detection of genuine alerts. This is beneficial for flight safety, as it helps controllers focus on issues such as conflict risks or resolution advisories. The enhanced algorithms developed for the STCA prototype led to more precise warnings and fewer false and nuisance alerts when compared against existing STCA technology.

Tests using real traffic data demonstrated the operational and system feasibility of the prototype for the identification of conflicts between flights. For instance: the false alert rate of the new system was 15 % lower than the existing system. The likelihood of controllers receiving unnecessary resolution advisories during a level-off encounter between two trajectories was shown to be reduced by a factor of between 30 and 70 with the introduction of additional functionalities.

The solution, which is available for industrialisation, is now implemented in 34 countries across Europe.

Human factors and local circumstances have a significant influence on determining what constitutes an operationally relevant conflict which must be alerted by STCA and what is an effective minimum level of nuisance/false alarms

BENEFITS

- Identification of conflicts, both en-route and in the terminal area
- Reduced false alert rate while maintained genuine alert rate and warning times are maintained
- Significant increase in safety of flight especially during complex operations





SJU references:
#69/Release 3

BETTER CONFLICT DETECTION TOOLS

Enhanced short-term conflict alerts (STCA) with downlinked parameters

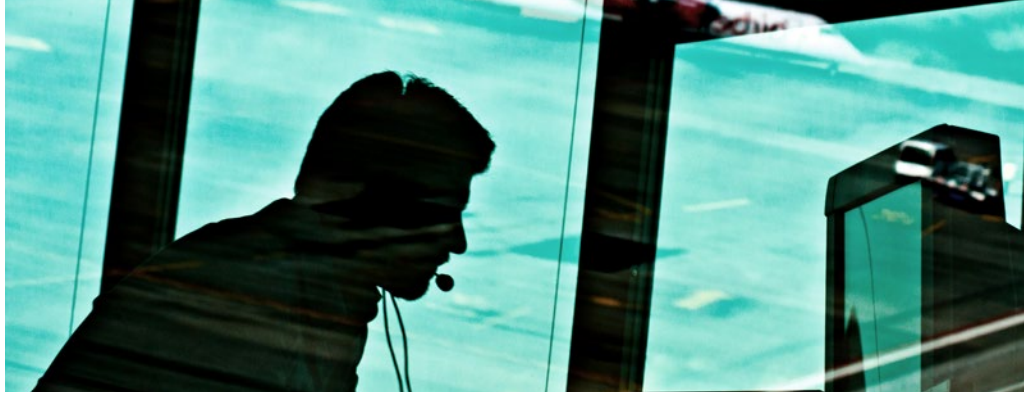
STAKEHOLDERS

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BENEFITS

- **Enhanced safety through reduced false alert rates and improved warning times of conflicts between flights**
- **Improved operational efficiency**
- **Increase of controller's situational awareness**

Short-term conflict alerts (STCA) provide controllers with a short-term warning of potential conflicts between aircraft in the same airspace. Enhancing the STCA safety net with information down-linked from the aircraft provides more accurate data on which to base warning signals.

Aircraft already transmit enhanced surveillance data using Mode S. In this SESAR solution, two Mode-S derived parameters were incorporated into the STCA logic: selected flight level and track angle rate. The former prompts the system to check if the aircraft intends to climb or descend to a certain flight level even before it begins the manoeuvre. This can detect an unsafe clearance given in error by the controller, or controller-pilot misunderstandings in radio transmissions, such as read back errors or instructions copied by a different aircraft. The latter - track angle rate - gives a better anticipation of how an aircraft will turn, and applies particularly in terminal airspace.

STCA with downlinked parameters was tested for both en-route and terminal airspace environments. The validation results confirmed the benefits in terms of reduction of nuisance alerts, while relevant alert rate was maintained or increased. Thus, controllers' trust in the STCA system increased. There was also evidence of improvements in alert warning time within the en-route environment as well as terminal airspace, chiefly due to the anticipation of the vertical evolution based on the downlink of the selected altitude.

This solution is implemented in 10 countries across Europe.

Controllers reported significant higher trust values with the support of downlinked parameters compared to the current version of short-term conflict alerts

Downlinked information confirming aircraft-selected flight level was the most relevant contribution to improved short-term conflict alerts





AVOIDING AIRBORNE COLLISIONS BY IMPROVING SURVEILLANCE DATA IN THE COCKPIT

SJU references:
#PJ.11-A1/
Release 9

ACAS Xa European acceptability framework



STAKEHOLDERS
ANSP
AO
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Airborne collision avoidance systems (ACAS) currently receive information only from Mode C/S interrogations, yet there are other surveillance sources available, such as the more accurate automatic dependent surveillance – broadcast (ADS-B), which could enhance this safety layer. In addition, the performance of collision avoidance can be improved by updating the mathematical processes and modelling used in today’s traffic alert and collision avoidance system (TCAS).

BENEFITS

- Enhanced safety
- Fewer nuisance alerts

Both these improvements form part of the ACAS Xa being designed for commercial aircraft with the aim of delivering the next generation TCAS in the 2020-2023 timeframe. By introducing additional surveillance data and optimised resolution advisories, ACAS Xa is expected to improve on today’s system without changing the cockpit interface, i.e using the same alerts and presentation.

ACAS Xa implements the surveillance improvement through a surveillance and tracking module (STM) which processes raw surveillance data coming from the surveillance sensors. Meanwhile the resolution advisory improvement is dealt with by the threat resolution module (TRM), which uses the estimated intruder parameters provided by the STM to choose an appropriate avoidance manoeuvre, if necessary.

SESAR validated the solution using multiple fast-time simulations combined with encounter models designed to replicate rare ACAS events, and one real-time simulation. ACAS Xa is a US Federal Aviation Administration development so SESAR tested the technology in a European environment. The results showed ACAS Xa improves safety in a theoretical environment by as much as 16% when all aircraft are equipped.

ACAS systems need to be interoperable worldwide which is primarily ensured through the standardisation process. The European requirements identified by SESAR are being fed into the global standardisation process.

The solution is available for industrialisation.



SJU references:
#105/Release 1

AUTOMATED AIRCRAFT COLLISION ALERTS

Enhanced airborne collision avoidance system (ACAS) operations using the autoflight system

STAKEHOLDERS

ANSP

AO

AU

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BENEFITS

- Safety levels are maintained
- ACAS operations are less disturbing for air traffic management and pilots
- Increased air navigation service provision
- Resolution advisories are more consistent
- Shorter response time for resolution advisories in general

Existing airborne collision avoidance systems (ACAS) triggers resolution advisories when a collision risk is predicted. Unnecessary alerts can be caused by aircraft correctly climbing or descending to a cleared flight level close to the level occupied by another aircraft. This can reduce the system's safety benefits and make air traffic control operations more complex. ICAO has recommended new altitude capture laws that automatically reduce the vertical rate at the approach to the selected flight level, reducing unnecessary resolution advisories.

SESAR partners conducted validation exercises that replicated the environment in which ACAS is being operated, and used different configurations to test the application of the new altitude capture rule compared with existing operations. The scenarios included testing aircraft in close encounters, where there is an actual risk of mid-air collision, and an in day-to-day encounters, in which the aircraft are not necessarily on a close-encounter course but where trajectories may trigger a conflict alert. The tests looked at safety, pilot acceptance, compatibility with air traffic control, and trajectory modification, to see if the new law improved the current situation.

The validation showed the new altitude capture law is very effective in reducing the number of resolution advisories triggered in 1,000 ft level-off encounters. The likelihood of receiving a resolution advisory was reduced by a factor of 30, and even 70 in one particular configuration. SESAR recommends implementing the altitude capture rule to reduce unnecessary ACAS alerts. It also recommends modifying the collision avoidance system to improve protection against multiple alerts.

The solution can bring significant operational benefits. By automatically reducing the vertical rate at the approach to the selected flight level, unnecessary alerts are reduced, increasing faith in the system, while reducing distraction on the flight deck. Compatibility with air traffic control operations has also been positively assessed.

The solution is available for industrialisation.

The solution triggers a safe automated response by the aircraft itself, instead of the current manual response performed by pilots

The new altitude capture laws aim to reduce unnecessary alarms generated by airborne collision avoidance systems

Optimised ATM network services

An optimised ATM network must be robust and resilient to a whole range of disruptions, including meteorological and unplanned events. An improved dynamic and collaborative mechanism will allow for a common, updated, consistent and accurate plan that provides reference information to all ATM actors involved in the planning and execution of flights. This feature includes activities in the areas of advanced airspace management, advanced dynamic capacity balancing (DCB) and optimised airspace user operations, as well as optimised ATM network management through a fully integrated network operations plan (NOP) and airport operations plans (AOPs), connected to the NOP via system-wide information management (SWIM).





SJU references:
#20/Release 5

SHARING INFORMATION IN REAL TIME

Initial collaborative network operations plan (NOP)

STAKEHOLDERS

ANSP

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BENEFITS

- Increased ATC network capacity
- Enhanced predictability
- Improved planning allowing for optimised routes
- Enhanced safety

The network operations plan (NOP) is a single window showing information in real time about the air traffic situation across the whole of Europe. Through the NOP, air navigation service providers, airlines, ground handlers, meteorological experts and airports can view the current situation and can coordinate their activities. Importantly, it connects the airports with the rest of the system by including capacity and operational data and shows where any likely pinch points might occur.

The SESAR Solution extends the collaborative NOP information structure to enable more data exchanges between the Network Manager and other partners in order to deliver greater operational efficiency. Additional automation tools support the process, and assist decision making and performance monitoring. The concept also uses system-wide information management (SWIM) to allow shared operational real-time decision making. The SESAR solution addressed three main aspects: the airport operations plan (AOP)-NOP integration, the meteorological status monitoring and the network performance monitoring.

Live trials in different locations looked at the feasibility and benefits of expanding the collaborative aspects of NOP, and the integration AOP-NOP, specifically by assessing the safety and technical feasibility of automatically updating controller displays when airspace users activate temporary airspace reservations in military airspace. The exercises aimed to identify the interoperability requirements between air traffic control, airspace users and the Network Manager.

Meanwhile, a series of shadow-mode exercises evaluated the use of the information sharing environment for assessing the impact of advanced short-term air traffic flow capacity management (ATFCM) measures (STAMs) on network performance. The exercises are also validated the integration of weather information into the network - including meteorological forecasts - to improve tactical demand capacity balancing measures.

The SESAR Solution is available for industrialisation. The solution will be deployed across Europe.

The solution enables the Network Manager and stakeholders to prepare and share information in real time and supports collaborative decision-making processes.

Data exchanges between the Network Manager, airports, airspace users and air traffic control carried out in real time contribute to greater operational efficiency





MORE EFFICIENT AIRSPACE MANAGEMENT

Automated support for dynamic sectorisation

SJU references:
#66/Release 2



STAKEHOLDERS
ANSP
AO
AU
NM

Spare airspace capacity can become available even at peak traffic times, but there are few tools available today to take advantage of this. Air traffic management systems can detect high traffic density, but do not – as yet – find alternative solutions to ease congestion. By adapting airspace configurations, this latent capacity can be used to help meet demand at peak times.

This SESAR automated solution considers the traffic needs, and groups or ungroups airspace sectors to match capacity with evolving demand. The support tool is used by the supervisor to determine sector planning on the day of operations and to manage staff resources accordingly. The result is better use of airspace and human resources, improved safety due to early management of constraints, and fewer delays.

During the validation activities, the automated support for dynamic sectorisation tool was used by the supervisor and flow manager to evaluate the most suitable en-route sector configuration and related staffing needs. The tool takes into account several information sources. These include demand data, including actual flight data as well as planned data; local constraints such as staff availability; and unplanned events such as bad weather or changes as a result of actions at other airports.

The validation of dynamic sectorisation showed that traffic capacity increased by 10 % during peak periods, while the number of delayed flights fell by 5 %. In addition, because the tools provided advanced warning, the air traffic management system was better prepared to manage these situations safely. The improved situational awareness avoided demand and capacity imbalances and enabled controllers to handle more flights per sector even during busy periods.

This solution is ready for industrialisation and is part of synchronised deployment plans across Europe.

Shadow-mode trials using the tool for automated support for dynamic sectorisation resulted in better use of available airspace and staff resources

The concept provides support for decision making based on sector configuration in order to optimise use of the controller work force

BENEFITS

- Improved safety due to increased situational awareness of supervisors
- Increased capacity due to better use of available resources, both human and airspace
- Reduced saturation periods and flight delays
- Increased cost efficiency





SJU references:
#31/Release 5

ADVANCED FLEXIBLE USE OF AIRSPACE

Variable profile military reserved areas and enhanced civil-military collaboration

STAKEHOLDERS

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BENEFITS

- Increased airspace capacity
- Optimised trajectories, thereby reducing track miles
- Improved safety

Traditional airspace classification of certain areas for either 'civil' or 'military' use has been superseded by the concept of flexible airspace use which allows the airspace to be allocated according to user requirements. The concept is achieved through enhanced civil/military coordination and plays a major role in delivering additional airspace capacity. However, its application is still largely confined to national airspace use rather than cross-border implementation, a situation that SESAR is working hard to change.

This solution offers greater flexibility by allowing dynamic airspace management in all phases of ATM operations, from initial planning through to the execution phase, taking into account local traffic characteristics. The solution includes support tools, operational procedures and processes for real-time airspace status data exchange and for managing variable profile areas (VPA). Planning operations can be enhanced by sharing airspace information in real time and supporting the collaborative decision-making process between the Network Manager, civil and military authorities, and airspace users. The aim is to achieve greater dynamic airspace management, accommodating local and network needs.

Live trials demonstrated the feasibility of automatically updating airspace status into the Network Manager system, and assessing the optimum technology solution that can put into an operational environment. The activities helped to refine the interoperability requirements so there is better exchange of data between the different parties. A series of shadow-mode trials validated the benefits of sharing and using aeronautical information for mission-planning purposes.

Flexible use of airspace allows users to have access on the basis of actual need

SESAR has validated the advanced flexible use of airspace in terms of connectivity using basic procedures and systems with limited functionality. SESAR's work is now concentrating on refining those procedures and further developing the functionality of the systems space.

The solution is now available for industrialisation and is being deployed across Europe.





BETTER TOOLS FOR COMPLEXITY RESOLUTION

Automated support for traffic complexity detection and resolution

SJU references:
#19/Release 5



Air traffic control uses flight plan data filed by airlines - indicating the routes they intend to fly - to safely and efficiently manage the airspace. Reality, however, can vary from planned operations, as aircraft encounter unexpected delays, weather disruption or can be re-routed to avoid bottlenecks. Providing local flow management positions (FMP) with more accurate information about traffic flow, as well as tools to predict complexity and traffic peaks, offers a more efficient way to reduce airspace complexity.

SESAR is replacing today's non-integrated tools with advanced software that can assess traffic demand and complexity based on continuously updated information from multiple sources. By applying predefined complexity metrics, FMPs at local level can take timely action to adjust capacity in collaboration with the Network Manager and airspace users. The result is more predictable traffic flow, fewer delays and enhanced safety.

The complexity assessment and resolution (CAR) tool operates in short-term and medium-term time horizons to balance workload across different sectors to maximise throughput without overloading or leaving airspace capacity unused. CAR is supported by automated tools which take into account the availability of airspace (due to weather, reservation, etc), sector capacity, operator preferences and overall network operations. Resolution of complexity problems requires the combination of automated detection tools and flexible deployment of human resources to ensure high levels of efficiency are sustained. It supports FMPs and supervisors in better tactical decision making, and delivers more predictable traffic flow.

Dynamic management of airspace structure helps to de-conflict traffic ahead of time, and optimises the use of controller resources

This solution enables flight management positions and supervisors to identify, assess and resolve local complexity situations, thereby reducing traffic peaks

Real-time simulations tested the automation tools in the en-route environment, and the extended arrival manager time horizon. Further real-time simulations assessed the concept of complexity measurement in a free route environment. The aim is to simplify the air traffic situation and enable controllers to optimise throughput with very little intervention.

This solution is available for industrialisation and is being deployed across Europe.

STAKEHOLDERS

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BENEFITS

- Increased ATC capacity
- Improved punctuality
- Increased cost efficiency
- Enhanced safety
- Reduced fuel and emissions





LESS WAITING AND FEWER DELAYS

Advanced short-term ATFCM measures (STAMs)

STAKEHOLDERS

ANSP

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BENEFITS

- Better use of airspace capacity in terminal and en-route airspace
- Increased cost efficiency
- Improved situational awareness of the European network

To avoid traffic overload, flights are typically held on the ground rather than added to congested flight paths. These precautionary measures can be imposed hours in advance and are based on flight plans. Short-term air traffic flow capacity management (ATFCM) measures (STAMs) have more flexibility to handle traffic overload since control measures are applied at a later stage and align more closely with actual demand. They also allow additional measures, such as temporarily constraining a flight or group of flights at a lower altitude, or imposing minimum re-routings, to prevent sector overload.

SESAR has developed advanced STAMs through sharing information between the Network Manager and area control centres which only impose a wider range of measures as and when necessary.

Through close cooperation between different actors, it is possible to target individual flights with a STAM measure, such as a minor ground delay, flight level cap, or minor re-routing, to take into account local preferred solutions, rather than apply a regulation to a group of flights as a whole.

Advanced STAMs include a set of automated support tools at the network level which detect hotspots and disseminate the information to flow management positions in the area control centres. The toolset also includes 'what-if' functionalities to evaluate what the effect of STAMs will be before effectively applying them. The information takes account of an expanded information set including weather, airport operations, runway occupancy and traffic complexity. The data is shared electronically with the possibility to use business-to-business (B2B) system-wide information management (SWIM) in the future.

STAMs not only improve visibility and predictability during operations, but also allow detailed post-operations analysis

SESAR's automated STAM tools allow a shared situational awareness of the STAMs applied across the network for flow management staff, and makes all STAM-related data available for detailed post-operational analysis.

This solution is available for industrialisation and is part of synchronised deployment plans across Europe.





MOVING TO TIME-BASED OPERATIONS

Calculated take-off time (CTOT) and target time of arrival (TTA)

SJU references:
#18/Release 5



As the airspace network and the airports become more connected, opportunities open up to smooth traffic flow and prevent imbalances between demand and capacity. This SESAR solution allows more intelligent demand and capacity balancing when traffic demand for landing into an airport exceeds the airport capacity (hotspot), by allowing the arrival airport to participate in the decision-making process of how to resolve the situation.

The solution aims at complementing departure regulations, such as the calculated take-off time (CTOT), with the dissemination of locally-generated target times, over the hotspot. Each airport collaborates with terminal area control to develop its own strategy to allocate the available landing capacity. Strategies are likely to take into account airspace users' input, the consistency of flight plans with seasonally-allocated airport slots, arrival route and runway allocation, or gate and connection management. This collaborative process contributes to a more coherent approach to demand regulation, which is expected to result in a reduced number of knock-on delays thereby benefitting passengers and airlines, as well as the network.

Another aspect of this SESAR solution is based on a greater level of information sharing between the Network Manager and flight operators. Whenever a flight is issued with a regulated take-off time, the airline also receives from the Network Manager the corresponding target time to arrive at the capacity-constrained area that motivated the regulation of its departure time. While target times are hard constraints, it is expected that the shared awareness will increase the effectiveness of air traffic flow management regulations. During the flight, any deviations between the agreed targets and the actual flight may be used by the different partners (flight crew, aircraft operator, local traffic managers) to support adherence to the time of entry in the congested area(s) and/or to assess and monitor the effects of deviations.

This solution involves the timely exchange of relevant airport and network information, resulting in common situational awareness which leads to improved network and airport planning activities, as well as improving operational performance

Live trials validated its feasibility with input from all actors involved. The trials included communicating planned measures (such as take-off and arrival time) as well as tactical measures imposed to maintain planned performance. The trials are also testing the use of sharing the same network view of the situation.

This solution is available for industrialisation and is part of synchronised deployment plans across Europe.

STAKEHOLDERS

- ANSP
- AO
- AU
- NM

BENEFITS

- Improved information sharing
- Enhanced predictability
- Improved situational awareness
- Increased capacity





SJU references:
#56/Release 4

WORKING IN PARTNERSHIP WITH AIRLINES

Enhanced air traffic flow management (ATFM) slot swapping

STAKEHOLDERS

ANSP

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BENEFITS

- Improved network performance (management and capacity)
- Improved environmental performance

Slot swapping is a means to reduce the impact of delays which may be caused by late inbound flights, weather conditions, airport congestion, among others. Slot exchanges within a single airline are agreed in a cooperative process with the Network Manager to smooth the traffic flow.

The SESAR solution enhances slot swapping functionalities by making it possible to swap pre-allocated slots with allocated slots or carry out multiple swaps for a single flight. These functionalities allow airlines to swap between long-haul and short-haul flights, or split the delay assigned to one flight between a maximum of three flights.

In current operations, when a flight is cancelled the Network Manager assigns its slot to another flight, usually operated by a different airline. This situation does not encourage flight cancellation, which results in the slots of cancelled flights being made available too late for them to be used by another flight. This solution allows airlines to promote one of their own flights in instances where they have to cancel a flight. This feature is expected to encourage cancellation of flights in the system, which would ultimately benefit all airspace users, particularly in capacity constrained situations.

Exercises simulating European city pairs validated this swapping tool which supported multiple swaps for a single flight, as well as substituting slots in case of cancellation. Over a seven-week time period, 199 swap requests were made using the tool with only 5 % rejected. The Network Manager reported that the response time to requests was not affected. Airspace users reported estimated savings of EUR 1 000 per flight.

It is not always easy to identify which flights would benefit from a swap. SESAR's enhanced slot swapping tool provides system support for the process, and makes it possible to carry out multiple swaps

The solution is available for industrialisation and has been implemented by the Network Manager..

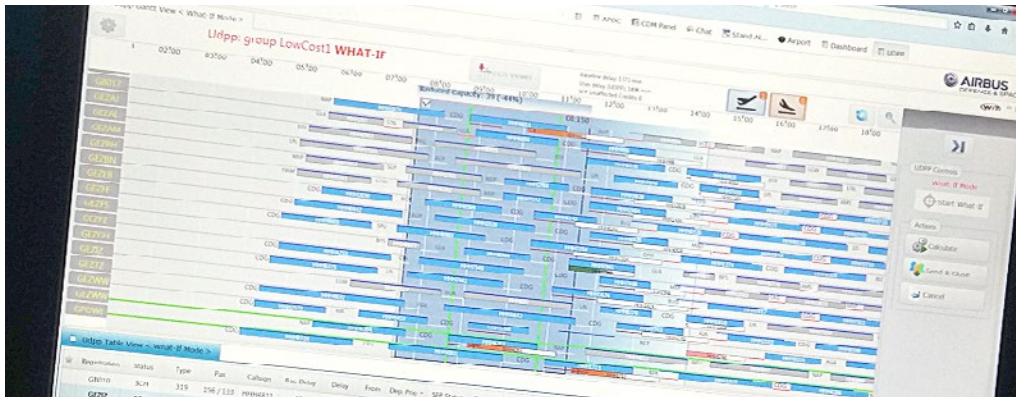




AIRLINE INPUT IMPROVES DEPARTURE OUTPUT

User-driven prioritisation process (UDPP) departure

SJU references:
#57/Release 4



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

The user-driven prioritisation process allows airlines to change the priority order of unregulated flights among themselves and in collaboration with the airport authorities. Airlines are given this flexibility in the pre-departure sequence (PDS) for last-minute disruptions, which usually lead to departure delays or cancelled flights.

A full-scale demonstration at a major European hub introduced the SESAR tool as part of the airport's existing pre-departure sequencing process. The Departure Flexibility (DFlex) project allowed airlines to re-order departures based on their operational requirements while still early in the planning stages. It also included a 'ready-to-depart' functionality to support an immediate swap for a flight that is ready for start-up. Participating airlines were given the opportunity to agree to a new target start-up approval time (TSAT) with air traffic control to optimise their schedules. Among benefits, the tool helped to manage a runway closure which otherwise would have prevented passengers making flight connections, and delays were selectively kept to a minimum for long-haul flights.

Offers a local solution for airlines at a collaborative decision-making airport to identify slot swapping opportunities in an easy and user-friendly way

BENEFITS

- Reduced airline delay costs in case of disrupted situations, without jeopardising airport and network performance
- Increased flexibility for airlines
- Improved environmental performance

The solution creates more opportunities for departure flexibility within a group of airlines, with benefits increasing as more airlines join. It requires a pre-departure planning process to function, for example using information already shared between operators about planned push-back, start-up and target take-off times. It is especially beneficial in case of disruption with significant financial benefits for the airlines.

This solution is available for industrialisation and is now implemented in France (Paris Charles de Gaulle), Germany (Dresden, Frankfurt, Hamburg, Munich, Nurnberg, Stuttgart and Berlin-Brandenburg airports) and Switzerland.





SJU references:
#PJ.07-01-01/
Release 9

ALL STAKEHOLDERS BENEFIT FROM CENTRAL MANAGEMENT OF CRITICAL FLIGHTS

Reactive flight delay criticality indicator (FDCI)

STAKEHOLDERS

ANSP

AO

AU

NM



BENEFITS

- Positive impact on safety
- Earlier management of critical flights
- Increased situational awareness for all actors

A delayed flight can be seen as important for several reasons: It may miss an important connection; an airport curfew may come with heavy cost penalties; expiry of crew hours; high passenger compensation; or few scheduled alternatives. Airspace users can share this information with the Network Manager (NM) through the use of the flight delay criticality indicator (FDCI) to help avoid or reduce delays. This solution applies to reactive FDCI flights that are delayed as a result of flow capacity management measures and highlights a preference to avoid more delay or decrease allocated delay where possible.

The FDCI is centrally monitored, traced and reported, and a simple set of agreed rules can be enforced to avoid its abuse. For example, it can only be applied to critical flights and a cap imposed on the number of FDCI requests per airline per period. Several variants of the concept are already used at local level by air navigation service providers and the Network Manager helpdesk, however this SESAR solution brings transparency of information at network level and provides a one-stop-shop for all airspace users.

The concept has been validated through shadow-mode trials using the NM validation platform. A human in the loop exercise included the NM, airline flight dispatcher, ATC flow manager and local traffic manager using different scenarios of traffic load and disruption in the network. The exercises showed that usage of FDCI is beneficial to the airspace user and increased situational awareness for all the stakeholders with an acceptable workload. A cost benefit analysis found airspace users would realise a positive return on investment within five years, based on the application of the solution for 10 critical flights per day at network level.

SESAR recommends establishment of a roadmap to deploy reactive FDCI operationally. Further validation work would help in the development of operational procedures and an initial module to be integrated in the NM eHelpdesk. There are no regulatory or standardisation requirements.

Network planning overall benefits from central monitoring of critical flights



NEW INFORMATION FLOWS FOR AIRSPACE USERS IMPROVE FILED FLIGHT PLANS

AOP/NOP departure information integrated in EFPL

SJU references:
#PJ.09-03-02/
Release 9



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

The network operations plan (NOP) developed during SESAR 1 is a powerful tool to help balance capacity and demand. The Network Manager (NM) receives up-to-date and reliable information from most of the major airports about departure planning information (DPI), including taxi time, planned departure runways and departure routes.

This solution defines new information flows to airspace users to provide full operational capability (FOC) about the departure phase of the flight in a more dynamic way. Integrating elements of the airport operations plan (AOP) and NOP is important for flight planning and helps to better align airspace user and NM trajectories, improve fuel prediction and support target times management.

Among potential applications of integrated AOP/NOP departure planning information, airspace users can take into account the planned taxi time and departure runway and nominate a preferred airborne route when filing the final flight plan. Alignment of the preferences of airspace users, NM and airports in the planning phase through the exchange of dynamic AOP/NOP departure information leads to increased predictability and a more accurate and up-to-date shared 4D trajectory.

SESAR JU partners analysed differences between planned departure routes by airspace users and NM; analysis of departure routes, runway and taxi times included in DPI messages in order to refine operational scenarios and use-cases; and shadow-mode human-in-the loop sessions involving dispatchers from various airlines. The exercises assessed technical feasibility of relaying information for an airline flight planning system and looked at some of the qualitative benefits.

The results showed the use of departure information as provided by AOP/NOP led to more accurate final flight plans and increased situational awareness.

The solution is ready for industrialisation with some minor additional work, for example, studying the impact on current rules relating to the prioritisation of information used in trajectory prediction. It relies on SWIM-based information dissemination and impacts the NM, airports, and airline flight dispatchers.

The solution delivers an improved and transparent regional network management supported by a dynamic and collaborative network operations plan.

The solution is available for industrialisation and has been implemented in the Czech Republic and Ireland.

BENEFITS

- Reduces impact of network constraints
- Improved accuracy of filed flight plans
- Enhanced safety and cost-efficiency



Enabling aviation infrastructure

The enhancements described in the first three key features will be underpinned by an advanced, integrated and rationalised aviation infrastructure, providing the required technical capabilities in a resource-efficient manner. This feature will rely on enhanced integration and interfacing between aircraft and ground systems, including ATC and other stakeholder systems, such as flight operations and military mission management systems. Communications, navigation and surveillance (CNS) systems, SWIM, trajectory management, common support services and the evolving role of the human will be considered in a coordinated way for application across the ATM system in a globally interoperable and harmonised manner.





SJU references:
#28/Release 5

SHARED DATA FOR IMPROVED FLIGHT EFFICIENCY

Initial ground-ground interoperability

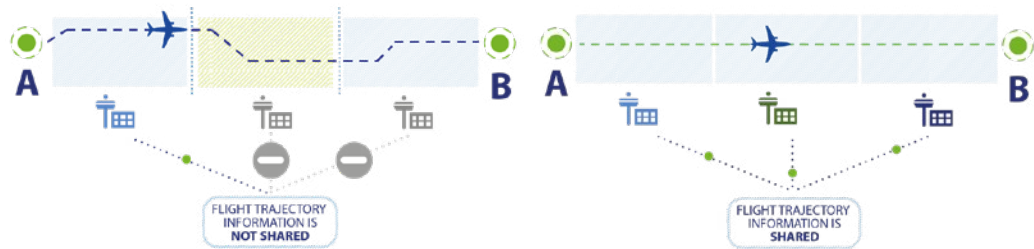
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BENEFITS

- Increased and easier access to information sharing
- Support standards update in preparation for deployment

Today, when an aircraft leaves one national airspace and enters another, the adjacent centres exchange a basic or minimum set of flight information through an on-line data interchange mechanism known as OLDI. Centres further downstream however, do not get access to this information straight away and must rely on the originally filed flight plan in order to organise their airspace. To address this, SESAR is developing Europe's first system for continuous exchange of flight information between all actors managing an aircraft at all stages of its journey.

The solution is based on a secure system-wide information management (SWIM) technical infrastructure (known as the SWIM blue profile) supporting the concept of the 'flight object' which is a single entity holding the most up-to-date information about a flight. The system allows controllers to conduct silent coordination between adjacent units. In this way, all air traffic control facilities hold a consistent view of the flight at all times, which supports seamless cross-border operations, including cross-border free route operations.

This solution represents a key enabler to support all ATM solutions that require an interface between different ground control centres (e.g. Free route operations).

Requirements are being scoped for the technical feasibility of flight data trajectory sharing between air traffic service units through the use of flight object. The information is used for the coordination of tasks and controller assistance services between different ground control centres. Requirements and use cases specify how the flight object can be used by air traffic control to provide the optimum flight profile for an aircraft, also known as the reference business trajectory.

Access to common flight data can result in more effective and better optimised coordination between adjacent ATC centres (or ANSPs)

Initial ground-ground interoperability represents a complete paradigm shift in how flight data information is shared between actors

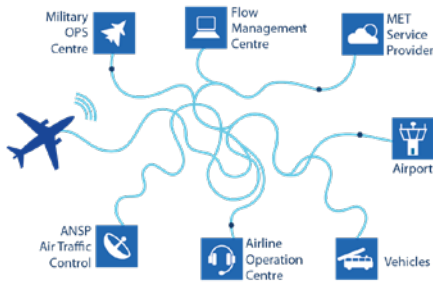
This solution has been consolidated with R&D activities on the integration of trajectory management processes (See PJ.18-02b).



LEARNING TO SWIM

Initial system-wide information management (SWIM) technology solution

SJU references:
#46/Release 5



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

SESAR is introducing a new approach to sharing information, called system-wide information management (SWIM). SWIM enables seamless information data access and interchange between all providers and users of air traffic management data and services.

The aim of SWIM is to provide information users with relevant and commonly understandable information. It does not refer to a single solution or technology, but rather a global level of interoperability and standardisation that enables users and providers to exchange data without having to use different interfaces or protocols. It is based on service-oriented architecture and open and standard technologies. It introduces a totally new way of working that sits comfortably in a cloud environment.

BENEFITS

- Increased cost efficiency and easily accessible information sharing
- Improved contextual awareness
- Improved collaborative decision making

This SWIM technological solution provides a coherent set of specifications to support standardisation in the context of SWIM deployment. These are the key elements in steering SWIM-enabled systems for ensuring interoperability are the following:

- ▶ Aeronautical information reference model (AIRM) to ensure semantic interoperability;
- ▶ Information service reference model (ISRM) to ensure organisational interoperability;
- ▶ SWIM technical infrastructure (SWIM TI) profiles and architecture to enable technical interoperability;
- ▶ SWIM registry to improve the visibility and accessibility of ATM information and services available through SWIM. It enables service providers, consumers, and the swim governance to share a common view on SWIM providing consolidated information on services that have been implemented based on SWIM standards.

SWIM represents a complete paradigm shift in how information is managed along its full lifecycle and across the whole European ATM system

The SWIM solution and services are developed in accordance with the ICAO SWIM manual

This solution is available for industrialisation and is part of Europe-wide synchronised deployment. The first SWIM-enabled solution was introduced in 2014 to support the exchange of data between neighbouring airspace sectors.





SJU references:
#PJ.17-01/
Release 9

SEAMLESS INFORMATION EXCHANGE BETWEEN PILOTS AND CONTROLLERS

SWIM-T1 purple profile for air/ground advisory information sharing

STAKEHOLDERS
ANSP
AO
AU
NM



BENEFITS

- Enhanced safety and security
- Contributes to global interoperability

SWIM enables ATM information to be exchanged between authorised stakeholders via interoperable services. It allows seamless information access and interchange between providers and users of ATM information and services. Taking advantage of service-oriented architecture (SOA) and open standards, SWIM supports operational improvements that depend on information exchanges to enable a better situational awareness and collaborative decision making.

This solution focuses on advisory information shared between airspace users and ground service providers including meteorological and aeronautical information. It aims to validate the SWIM air/ground infrastructure necessary to support ATM operational improvements based on non-safety-critical services. Air traffic control and flight crews benefit from more informed decision making as a result of this bi-directional near real-time information exchange. This SWIM application requires a set of aircraft and ground capabilities including a set of interface standards, together with infrastructure architecture and configuration aspects. As it is used for high latency, low bandwidth operations rather than real-time applications, it meets SWIM technical infrastructure purple profile criteria.

SWIM related activities require implementation of SWIM governance

SESAR members and partners tested the capabilities and robustness of the air/ground SWIM interface, performance when multiple SWIM nodes are in use, and several aircraft communicating simultaneously. The research also considered security aspects such as authentication, authorisation and monitoring capabilities. Technical validations were used to assess target specification for elements such as data link modes, use cases and security controls, and metrics applied to evaluate reliability, time behaviour and message integrity. SESAR also carried out a high-level comparison between the SESAR air/ground SWIM solution and the US Federal Aviation Administration (FAA) Aircraft Access to SWIM development.

The results were validated in several exercises and enabled development of architectural description and specification covering functional, non-functional and interface requirements for SWIM technical infrastructure purple profile air/ground applications. Based on the analysis of the results and the conclusions, recommendations were also made for next maturity phase, regulation and standardisation initiatives.

The solution is available for industrialisation.



TOWARDS SEAMLESS OPERATIONS

Flight object interoperability

SJU references:
#PJ.18-02b/
Release 10



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

An essential component of the future system is ground-to-ground interoperability (IOP), a solution designed to enable the swift and seamless exchange of flight trajectory information in real time between Europe’s network of air traffic control centres.

This solution addresses a frequent problem that affects Europe’s air traffic, whereby flights crossing borders or different airspace sectors have to adjust their trajectory or speed to avoid conflicts with other aircraft. The problem is caused largely by en-route control centres sharing information in a sequential way and updating the trajectory information.

With this solution, control centres involved in the management of a flight can share reliable, complete and updated flight trajectory information from take-off to landing, taking into account any existing and shared internal restrictions in the airspaces that the flight will cross.

The solution will also help carry out the ATC process “quietly”, without the need for the air traffic controller to coordinate with his/her counterparts in adjacent centres by phone. For this purpose, and implementing the “flight object” concept, all control centres share the same information and have the possibility to request changes to flight trajectories in real time.

The end goal is to attain a smoother control process, which will improve the efficiency of air traffic control in Europe and make it possible to manage more flights with greater precision and punctuality, offering cost savings to airlines, reductions in CO₂ emissions and ultimately providing a better service for passengers.

The solution, which is linked to ED133A standard is available for industrialisation and implementation.

BENEFITS

- **Increased predictability**
- **Increased cost efficiency**
- **Improved fuel efficiency**

All actions carried out in one centre are immediately visible in all other centres, removing any uncertainty over the conditions under which a flight would enter another airspace.

This solution is linked to EUROCAE ED-133A



SJU references:
#115/Release 5

GETTING CONNECTED

Extended projected profile (EPP) availability on the ground

STAKEHOLDERS

ANSP

AO

AU

NM



BENEFITS

- **Increased ground situational awareness resulting in increased predictability**

Modern aircraft feature advanced computerised flight management systems (FMS) to guide their navigation, which can exchange relevant data with the airline operations centres (AOC). Air traffic control centres, in turn, have sophisticated flight data processing systems (FDPS) to manage flight data on the ground, but there is limited data connection between the FMS and air traffic control ground systems.

The initial trajectory information sharing solution is based on the aircraft downlinking trajectory information directly from the FMS to the ground systems via an updated standard for the automatic dependent surveillance contract (ADS-C) that is used today exclusively for oceanic and remote operations. The newly developed standard is called ATN Baseline 2 and targets all operations. It allows the i4D FMS to downlink the extended projected profile (EPP), which contains an updated FMS route prediction. The data in the new standard is much more detailed than in the current ADS-C reports used in oceanic airspace; it includes, for example, the predicted aircraft weight, as well as the predicted horizontal and vertical speeds on up to 128 future waypoints along the route.

In this initial solution, the ground systems will enable controllers to display the downlinked route on the radar screen and will also automatically cross-check whether the downlinked route is consistent with what was expected on the ground; controllers will receive a warning in case a discrepancy is identified.

This solution is ready for industrialisation. It is being deployed in a synchronised way across Europe.

Increased data connectivity between on-board systems and ground air traffic control systems is a key enabler for the modernisation of the ATM system





PLANNING IMPROVES WITH ACCURATE FLIGHT DATA

AOC data increasing trajectory prediction accuracy

SJU references:
#67/Release 2



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

Europe’s vision to achieve high-performing aviation by 2035 builds on the idea of trajectory-based operations – meaning that aircraft can fly their preferred trajectory while minimising constraints due to airspace and service configurations. SESAR has introduced an early version which makes use of flight planning data sourced from airline operational control (AOC) to help controllers optimise aircraft flight paths. This solution represents an initial step towards the extended flight plan solution and flight and flow information for a collaborative environment (FF-ICE).

BENEFITS

- Increased predictability
- Increased safety

Access to flight planning data enables air traffic control to create more accurate trajectory predictors (TP) based on the intentions of the aircraft. The TP are used by advanced controller tools to detect potential conflicts and to develop efficient arrival and departure streams. Eventually, when new datalink communications are universally applied, trajectory information will be exchanged directly between the aircraft and the ground, anticipated from 2025 onwards.

The flight data provides information about aircraft climb and descent speed, and take-off mass, and can be used to help create trajectory profiles to meet five-minute up to two-hour time horizons. The data is particularly helpful when creating climbing and descending flight profiles, where current tools can encounter limited controller acceptance due to high false alerts and re-sequencing rates which result from the poor accuracy of trajectory predictions.

Trajectory information provides air traffic control with the degree of accuracy it needs to build sequencing or conflict-detection and resolution tools which support controllers’ tasks

A real-time simulation in a complex terminal airspace resulted in a 10 % reduction in medium-term conflict-detection false alerts when the underlying technical profile is supported by AOC data. Air navigation service provision was improved since fewer false alerts meant controllers had to perform fewer unnecessary actions, and airlines consumed less fuel as a result of fewer level-offs.

Most of the benefits expected from this concept occur in flight segments with strong ascending and descending profiles such as terminal airspace

An initial implementation has take place in the UK.

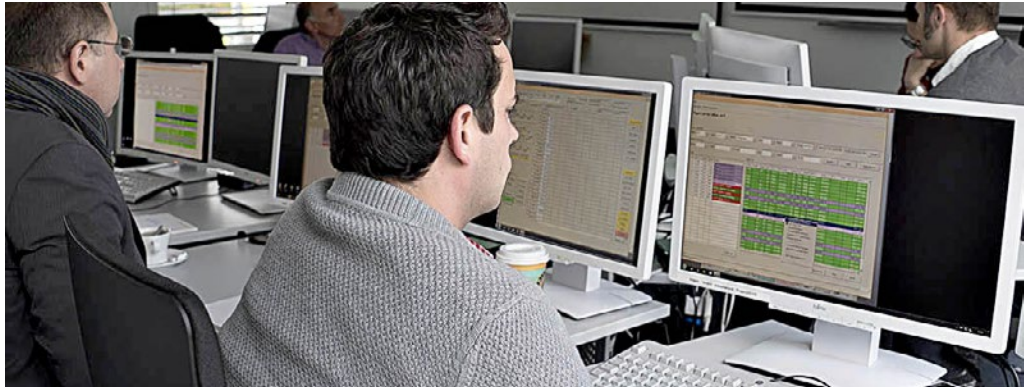


SJU references:
#37/Release 5

IMPROVED PLANNING THANKS TO ENRICHED DATA

Extended flight plan

STAKEHOLDERS
ANSP
AO
AU
NM



BENEFITS

- Improved network predictability
- Enhanced safety
- Improved performance of conflict detection and resolution tools

Air navigation service providers use aircraft flight plan data to plan and schedule air traffic in order to balance airspace supply and demand. In Europe's future trajectory-based flight environment, where aircraft can fly their preferred flight paths without being constrained by airspace configurations, flight plan data will include additional information, which will allow both the Network Manager and the air traffic control units to have a more precise plan of how the aircraft will fly.

The extended flight plan (EFPL) goes beyond the ICAO minimum requirements for aircraft flight plans, which were updated in 2012, with yet more operational data. In addition to trajectory data and aircraft performance data (compared to the ICAO flight plan), a key part of the concept allows for applied airspace management constraints and accepted trajectories to be sent from the Network Manager to the airspace users.

The EFPL includes further information relevant to each point of the aircraft's trajectory, for example speed and aircraft mass, as well as other performance data such as planned climb and descent profiles. This allows both air traffic control and the Network Manager to improve their prediction of the trajectory. This is especially relevant in complex airspace, because it allows better flow management, and also improves the performance of the conflict detection and resolution tools used by controllers.

The EFPL aims to reduce flight plan rejections by the Network Manager and increase traffic predictability. Concerning the flight plan rejections, the use of 15 data fields in the ICAO flight plan is open to different interpretations resulting in unwarranted flight plan rejections. The validation of this SESAR solution has included the refinement of the data exchange processes and shows that EFPL significantly reduces flight plan rejections compared to those associated with the ICAO 2012 flight plan validation process.

The extended flight plan includes additional information in relation to an aircraft's planned four-dimensional trajectory which supports an airspace environment where aircraft can fly their preferred flight paths

This solution sees the integration of four-dimensional flight plan data into the Network Manager flight planning acceptance and distribution system

The solution is available for industrialisation and is part of synchronised deployment.





ENRICHED TRAJECTORY DATA LEADS TO BETTER FLIGHT PLANNING

EFPL supporting SBT transition to RBT

SJU references:
#PJ.18-02c/
Release 9

STAKEHOLDERS

- ANSP
- AO
- AU
- NM

Airspace users share their flight plans with stakeholders on the ground so flights can be managed as closely as possible to their ideal profile. This shared business trajectory (SBT) is progressively refined prior to departure to create a reference business trajectory (RBT) agreed by air traffic control and the airspace user. This becomes the flight plan that is then filed. SESAR 1 introduced an extended flight plan (eFPL) to expand the information available for this collaborative decision-making process in order to improve trajectory prediction. The enriched data set is reflected in ICAO’s long-term vision of flight and flow information for a collaborative environment (FF-ICE).

SESAR JU partners set out to improve ATC prediction to better assess the expected sector load and reduce the number of false conflict detections. This solution expands the information exchange to distribute enhanced eFPL data to improve alignment of trajectories between air traffic control and airspace users. Included in this broader information exchange is the filed trajectory and agreed trajectory – with airport standard arrival and departure routes – as well as flight specific performance data, which allows air traffic control to recalculate, when needed, a trajectory closer to the preferred trajectory as would be generated by the airspace user. The activity supports trajectory-based operations by helping to align and unify air traffic control and airspace users’ trajectories in the pre-flight phase, and improves target time management for the network as a whole. The solution is part of European synchronised deployment.

This solution contributes flight safety and efficiency

BENEFITS

- Increased cost efficiency
- Enhanced safety and security

This solution covers two technical enablers and one standardisation enabler to support eFPL distribution to air traffic control. SESAR JU partners tested eFPL data transfer between the Network Manager and air traffic control; and a real-time simulation using Swiss airspace. The validation exercises demonstrated the technical capability of the distribution of eFPLs from the Network Manager to air traffic control using the business-to-business services. It also showed the ability of ATC Flight Data Processing systems to treat flight plan data from the eFPL format. The solution is available for industrialisation and is part of Europe-wide synchronised deployment.





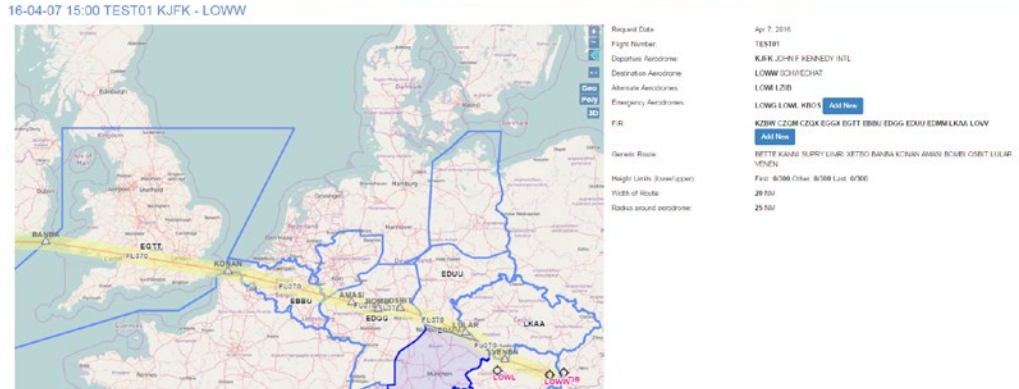
SJU references:
#34/Release 5

THE BENEFITS OF DIGITAL DATA

Digital integrated briefing

STAKEHOLDERS

- ANSP
- AO
- AU
- NM



BENEFITS

- Enhanced information sharing
- Increased cost efficiency through improved service provision
- Improved situational awareness

The current pre-flight briefing for the pilot includes pages of information, called notice to airmen (NOTAM), recent weather reports and forecasts (MET), which have to be integrated into a consolidated operational picture. The documents can be difficult for pilots to use, and no longer satisfy today's air traffic needs for timely and accurate aeronautical and meteorological information updates. By introducing digital NOTAM and MET data, the briefing could be radically improved.

Aircraft are increasingly equipped with electronic flight bag (EFB) devices which support pre-flight briefing to the pilot and on the ground through provision of flight documentation. The pre-flight briefing could take place directly on the EFB, receiving digital briefings from the ground and updated over a datalink during the flight. Retrieval of the digital aeronautical data, including NOTAM and MET data, is enabled by means of system-wide information management (SWIM) and digital NOTAM.

SWIM information exchange and digital NOTAMs can support the graphical representation of data such as meteorological charts, as well as increase the usability of briefing material by making it searchable and interactive. The digitised information can also be validated and cross-checked automatically (unlike today's pre-briefing documents) to ensure adherence to ICAO standards and to reduce risk of error. In addition, relevant information can be selected more easily from digital data compared with briefing notes which may include between 10 and 50 pages for a cross-European flight.

Real-time simulations assessed enhancements in pilot briefing applications based on digital NOTAMs, digital MET, and air traffic flow management data, with the aim of improving situational awareness for pilots and reducing briefing times.

In terms of benefits, the graphical presentation of digital information, better filtering automatic notification of relevant changes and a more logical organisation of the pre-flight information bulletins can improve pilot and dispatcher awareness, reduce briefing times and reduce the risk of information being misunderstood or missed.

This solution is available for industrialisation and is part of Europe-wide synchronised deployment.

This solution aims to improve pre-flight information sharing between pilot, flight dispatchers and air traffic controllers through the exchange of easier to understand, better filtered digital aeronautical data

The SESAR solution is aligned with the ICAO roadmap for the provision of digital aeronautical information on a global scale and mirrors parallel development in the US

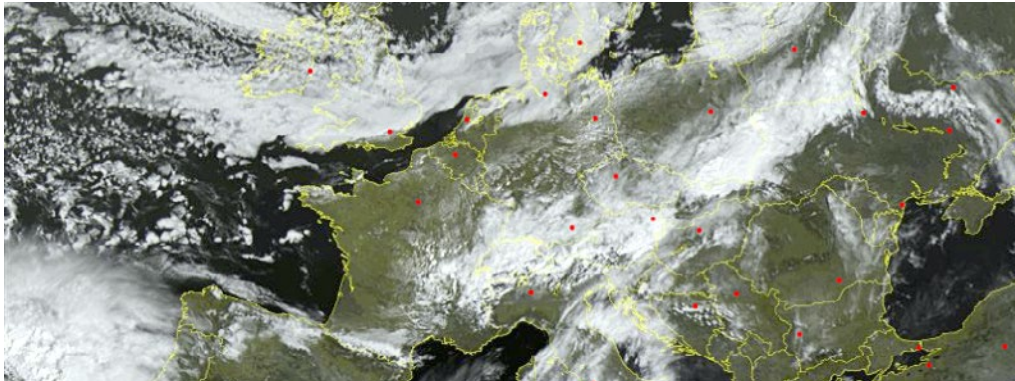




STAYING AHEAD OF THE WEATHER

Meteorological information exchange

SJU references:
#35/Release 5



Bad weather brings unwelcome disruption to flight schedules and is the cause of approximately 13 % of Europe’s primary delays. Yet the impact can be mitigated by the timely sharing of information so that effective recovery strategies can be put in place.

Meteorological information is currently available in several message formats and also in the form of maps or charts and plain text. Although end users are accustomed to these formats, they limit the opportunity to use the data effectively, for example to prioritise key information, or highlight relevant weather phenomena. Access to more precise weather data can assist decision making when it comes to flight planning, resource planning, and route planning, and can help to avoid unnecessary delay.

SESAR developed a mechanism by which meteorological data generated by European meteorological agencies can be seamlessly integrated into aeronautical information service provision; this is known as the four-dimensional (4D) weather cube. The 4DWxCube is a (virtual) repository of shared consistent and translated meteorological information, produced by multiple meteorological service providers (METSPs) and made available to airspace management stakeholders via its system-wide information management (SWIM) compliant MET-GATE.

Sharing this weather information and its integration within the air traffic management decision-making process enables airspace users, airports and air navigation service providers to stay up to date with the latest weather situation, and to plan accordingly and effectively. Weather conditions influence all aspects of air traffic operations, for example by increasing or decreasing tailwind, by changing pressure or temperature or by introducing low-visibility conditions.

The meteorological information exchange uses SWIM to enable seamless interchange of meteorological data with different partners, and involves SWIM-compliant services such as legacy forecasts (METAR/TAF/SIGMET) and new ones such as hazardous weather (convection, turbulence, icing) developed under the scope of this solution.

This solution is available for industrialisation. MET information exchange is being deployed as part of initial SWIM as part of Europe-wide synchronised deployment.

STAKEHOLDERS

- ANSP
- AO
- AU
- NM

BENEFITS

- Improved safety
- Improved planning, leading to fuel reduction
- Increased cost efficiency through improved service provision

The SESAR 4D weather cube makes use of actual and forecast MET information from different air and ground sources for providing adverse weather alerts

This solution builds on ICAO Annex 3 standards and recommendations, and contributes to the definition of MET standards





SJU references:
#PJ.18-04b-01/
Release 9

ACCESS TO ACCURATE AND TIMELY WEATHER DATA ENHANCES SAFETY

Ground weather management system (GWMS)

STAKEHOLDERS

ANSP

AO

AU

NM



BENEFITS

- Increased cost efficiency
- Enhanced safety and security

Weather conditions have a big impact on aviation. Strong headwinds can extend travel time while sudden storms can affect departures and arrivals as aircraft avoid hazardous conditions. Understanding local weather close to the aerodrome increases flight safety and efficiency, especially when meteorological information can be integrated into decision-making processes. SESAR is improving meteorological information services and capabilities to enhance accurate and timely delivery of information and make it compatible with SWIM.

The solution builds on SESAR 1 work to make weather information available to ATM stakeholders from the four-dimensional weather cube (4DWxCube) – a virtual repository of shared information from multiple meteorological service providers – via its SWIM compliant MET-GATE. The latest research focuses on adapting, prototyping and validating the MET-GATE functional block. SESAR proposes two solutions: The ground weather management system (GWMS) and associated glide path wind profile capability; and METForTAM information service, both designed to improve situational awareness and decision-making.

The solution uses existing sensors and MET capabilities and conforms with SWIM technical infrastructure yellow profile.

A technical validation examined whether the developed components could be incorporated in various ATM systems and meet the operational objectives. Two exercises showed the requirements could be met, including down- and uplink services, in accordance with SWIM technical infrastructure yellow profile i.e. based on web services with no real-time or near real-time requirements.

The new capability glide wind profile has been developed as the provider of glide wind data to the GWMS using mature sources like radar and Lidar sensors. The purpose is to enhance separation procedures based on the collected wind data.

SESAR recommends development of additional SWIM services centred around local MET capabilities and requirements, in addition to a long-term validation exercise to test handling several services at more than one airport to demonstrate the full capabilities of 4DWxCube. This would serve to demonstrate the benefits compared with currently available meteorological information and data provision.

The solution is available for industrialisation and has been implemented in Austria and Ireland.





SATELLITE WEATHER DATA SUPPORTS SAFE AND SMART FLIGHT PLANNING AROUND HAZARDS

SJU references:
#PJ.18-04b-02/
Release 9

Improved MET information services



Aircraft already access valuable weather information through atmospheric observations during flight to avoid current weather hazards. In addition, geostationary satellites detect, track and nowcast thunderstorms beyond the limited view of on-board radar, enabling aircraft to strategically plan a safe and smart flight route around the thunderstorms well ahead in time instead of flying tactical manoeuvres and searching for gaps between the thunder cells. Using data on cumulonimbus (Cb) clouds, Cb-global detects, tracks and predicts thunderstorms. SESAR Cb-global data and Cb-global service enables airline operations centres to use this satellite weather information to improve flight planning.

Cb-global capability is a mature technology, developed during previous European research. SESAR expands this and addresses the delivery of Cb-global data through SWIM technical infrastructure. The data does not require real-time delivery so the service can be supported by SWIM technical infrastructure yellow profile.

The solution applies the principles and guidance defined by SWIM technical infrastructure yellow profile.

SESAR JU partners performed two technical validation exercises for the developed capability and service. The first exercise looking at capability validated that Cb-global is able to detect and nowcast thunderstorms (Cb), convectively induced turbulence (CIT), and high-altitude ice-crystals (HAIC) and assessed contribution of Cb-global information in terms of potential performance benefit. The exercise focusing on the Cb-global service validated the service is able to provide Cb-global data through a SWIM technical infrastructure yellow profile to the flight management operation at a civil airspace user operation centre.

A statistics assessment compared real flown flight routes with planned routes optimised on the basis of Cb-global information identified potential fuel savings up to three tonnes per flight, fewer avoidance manoeuvres and less alternate landings. Regarding the Cb-global service, the validation results show that service was able to provide the data in the appropriate format in real time mode to the data consumer.

The use of Cb-global as an additional strategic planning tool brings operational benefit. This benefit increases if the Cb-global information is used both in the air and on the ground for a common information sharing and common decision making. The solution is available for industrialisation and has been implemented in Ireland.

STAKEHOLDERS

ANSP

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BENEFITS

- Increased cost efficiency
- Enhanced safety and security
- Potential fuel savings





SJU references:
#100/Release 5

VISUALISING AIRBORNE ALERTS FROM THE GROUND

ACAS ground monitoring and presentation system

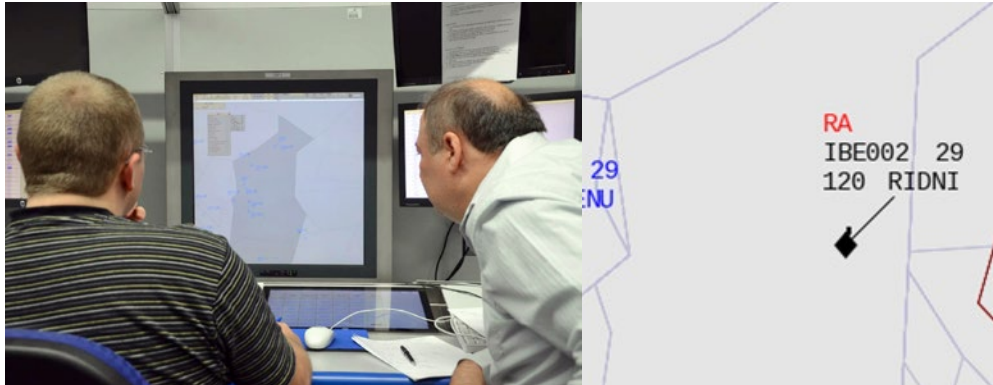
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BENEFITS

Enhanced safety

The airborne collision avoidance system (ACAS) provides resolution advisories (RAs) to pilots in order to avoid collisions. Controllers rely on pilots to report RAs by radio as they occur in accordance with ICAO regulations. However these reports can come late, incomplete or are absent in some instances. This solution consists of a set of monitoring stations and a server system, which enable the continuous monitoring and analysis of ACAS RAs and coordination messages between airborne units from the ground.

The system includes the potential to provide real-time airborne data to ground-based safety nets. For ACAS RA monitoring, the ground station is extended to be able to receive 1030 MHz messages exchanged between ACAS equipped aircraft and the RA broadcast that can provide information on the presence of an RA.

A test platform was used to monitor the entire upper airspace during a period of more than three years to collect data and evaluate the concept. The system was able to process and deliver valid resolution advisories within two seconds, and was able to filter out false advisories.

The SESAR validation work also showed that the fusion and the use of surveillance sensor data from Mode-S radar, wide area multilateration (WAM), multilateration (MLAT) and ADS-B, when combined with ACAS ground sensor RA data provide practical and beneficial safety enhancements.

SESAR exercises show that ACAS monitoring on the ground is feasible and can be integrated into an overall air traffic management system

This solution is available for industrialisation but further work is expected to address the operational use by controllers. The solution has been implemented in Austria, Czech Republic, Denmark, Hungary and the UK (for post-operational analysis and dashboarding).

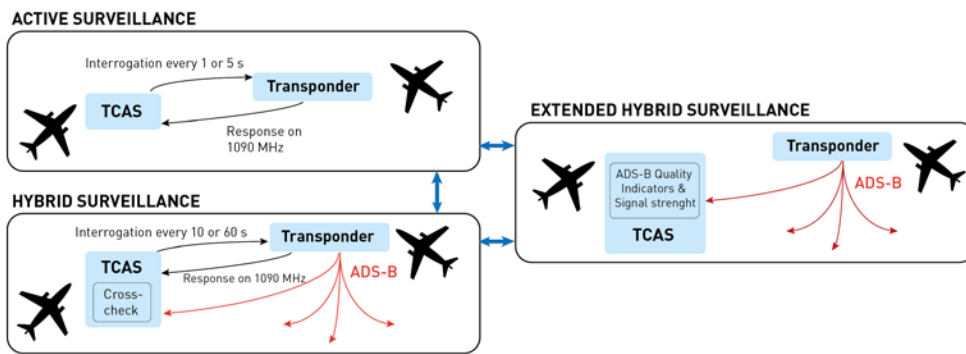




SPECTRUM EFFICIENT SURVEILLANCE

Extended hybrid surveillance

SJU references:
#101/Release 5



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

BENEFITS

- Reduced risk of radar information loss due to overloaded frequency band

The traffic alert and collision avoidance system (TCAS) is an airborne collision avoidance system designed to reduce the incidence of mid-air collisions between aircraft. Currently, TCAS II is dependent upon 1090 MHz replies that are elicited by 1030 MHz interrogations. These provide the pilot with information about the relative distance, bearing and aircraft altitude and are used to build active tracks. However, the process uses precious frequency bandwidth that is also needed for surveillance purposes.

The technical solution consists of an enhanced TCAS capability, adding passive surveillance methods and reducing the need for active Mode-S interrogations. By making fewer active interrogations, this solution allows the aircraft to significantly reduce the usage of the 1090 MHz frequency.

Validations carried out using roof-top antennae in the proximity of an airport showed the basic functionality of the system. The concept was also flight-tested and this data was used in simulation activity to assess the results and overall impact on 1090 MHz load. The technology met the minimum operating requirements developed for the solution and resulted in no operational differences for pilots and controllers. When the 1090 MHz usage was compared with TCAS II, the assessment showed a reduction of Mode-S interrogations of at least 70 %.

Minimum operational performance standards (MOPS) for improved hybrid surveillance has been already published both by EUROCAE (ED-221) and RTCA (DO-300A)

This solution is available for industrialisation.



SJU references:
#102/Release 5

ENTERING THE NEW DIGITAL ENVIRONMENT

Aeronautical mobile airport communication system (AeroMACS)

STAKEHOLDERS

ANSP

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BENEFITS

- Increased capacity for information and communications exchanges
- More efficient airport surface operations with increased safety and security levels
- Increased cost efficiency, thanks to synergies and sharing of infrastructure between actors, thereby lowering costs

ATM communications capacity is reaching saturation in Europe due to increasing air traffic volumes and density. The situation is particularly acute on the airport surface where a large concentration of aircraft combined with pre-flight and post-flight operations increasingly rely on data communications.

The aeronautical mobile airport communication system (AeroMACS) offers a solution to offload the saturated VHF datalink communications in the airport environment and support new services. The technical solution AeroMACS is based on commercial 4G technology and uses the IEEE 802.16 (WiMAX) standard. Designed to operate in reserved (aeronautical) frequency bands, AeroMACS can be used for air navigation service providers (ANSPs), airspace users and airport authority communications, in compliance with SESAR's future communication infrastructure (FCI) concept. AeroMACS is an international standard and supports globally harmonised and available capabilities according to ICAO Global Air Navigation Plan (GANP).

SESAR validated the system concept and usage of the airport surface datalink system. This has been done through simulations, developing prototypes and testing in lab conditions as well as on-site at airports and on aircraft. In addition, SESAR led the development of standards in ICAO, EUROCAE/RTCA and the Airlines Electronic Engineering Committee (AEEC). Together with other FCI solutions, AeroMACS will support the multilink FCI concept, offering increased robustness of datalink operations and thereby supporting the move towards the use of datalink communications as the primary means of communications in airspace management.

This solution is available for industrialisation. Implementation will be subject to the demonstration of a viable business case.



A HIGH-PERFORMANCE REPLACEMENT FOR CONGESTED COMMUNICATION CHANNELS

AeroMACS integrated with ATN, digital voice and multilink

SJU references:
#PJ.14-02-06/
Release9



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

Air traffic management communications capacity is reaching saturation because of the increasing air-traffic volumes and density. The problem is most severe on the airport surface where the large concentration of aircraft is combined with pre-flight and post-flights operations, increasingly relying on communications such as VHF datalink.

AeroMACS is a high-performance secure airport data link technology identified by ICAO to support the future communication infrastructure (FCI). It provides a mature and validated choice to support the future air navigation service provider (ANSP), airline and airport authority datalink communication exchanges in the airport environment between mobile and fixed users, providing worldwide interoperability and integration of critical communications. SESAR 1 validated AeroMACS datalink access link integration with the aeronautical telecommunications network (ATN) to handle data and voice air/ground communications. SESAR 2020 expands this to include both open systems interconnection (ATN/OSI) and internet protocol suite (ATN/IPS), as well as voice over internet protocol (VoIP) digital voice communication and multilink in ATN/OSI environment. Multilink capability enables AeroMACS to be part of the FCI together with L-DACS and SATCOM.

AeroMACS is based on IEEE 802.16-2009 (WiMAX) standard and operates in reserved aeronautical frequency band

BENEFITS

- **High capacity data exchange**
- **Worldwide interoperability**
- **More efficient surface operations**

SESAR 2020 carried out specific exercises to validate integration of these technologies using technical validation platforms. The tests exchanged controller-pilot messages using ATN/OSI, ATN/IPS, multilink exchanges and digital voice. They showed the AeroMACS access link provides better support to air traffic and airlines due to its large bandwidth and high throughput. It easily supports increasing levels of service on the airport surface and its security features offer valid protection against intentional attacks. It also benefits ANSPs and communication service providers due to the secure communication link and ability to support emerging services including controller pilot datalink communications (CPDLC); and airport authorities can use AeroMACS for additional applications such as emergency airport services, gate, luggage, airport service vehicles, etc.

The solution is available for industrialisation.



SJU references:
#109/Release 5

A NEW GENERATION OF SATELLITE-BASED DATALINK COMMUNICATIONS

Air traffic services (ATS) datalink using Iris Precursor

STAKEHOLDERS

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BENEFITS

- **Enabler for initial i4D operations**

The Iris Precursor offers a viable option for air traffic services (ATS) datalink using existing satellite technology systems to support initial four-dimensional (i4D) datalink capability. The technology can be used to provide end-to-end air-ground communications for i4D operations, connecting aircraft and air traffic management ground systems.

The Iris Precursor is designed to exploit an opportunity to deploy an aviation communications service based on the existing SwiftBroadband (SBB) satellite network from Inmarsat. The aim is to augment the existing VHF datalink (VDL) capability in Europe in order to increase reliability and capacity, and help establish satellite communications as a key component in the future ATM communications landscape. This solution also offers an alternative datalink option for aircraft already equipped with SATCOM systems.

A SESAR flight trial demonstrated that the Iris Precursor service could provide the communication performance required for datalink exchanges to fly i4D operations. Specifically, it showed how i4D automatic dependent surveillance-contract (ADS-C) could be successfully maintained with two air traffic control centres for over two hours. During this time, i4D ADS-C reports were generated on events resulting in downlinking trajectory updates approximately every 20 seconds with 20 waypoints - an update rate which is well above the rate needed for i4D trajectory exchanges. In addition to the i4D trajectory exchanges, various controller-pilot datalink communications (CPDLC) messages were exchanged along the flight with a remarkable performance round trip time of below two seconds throughout the flight's duration.

This solution is available for industrialisation and a number of States are planning to implement the solution (France, Portugal and Spain).



IMPROVING SURVEILLANCE SECURITY AND INTEGRITY

ADS-B surveillance of aircraft in flight and on the surface

SJU References:
#110



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

Automatic dependent surveillance-broadcast (ADS-B) is a technique which allows the tracking of aircraft in flight and on the surface. Enhancements of the functionality and interfaces are required to the ground surveillance system, in order to make it compliant with the new applications of ADS-B in radar airspace, ADS-B for airport surveillance and other emerging requirements, such as security.

BENEFITS

- Enabler for surveillance infrastructure rationalisation

The SESAR solution consists of ADS-B ground station and surveillance data processing and distribution (SDPD) functionality. The solution also offers detection and mitigation techniques against deliberate spoofing of the ground system by outside agents. These techniques can also be used to cope with malfunctioning of avionics equipment. SESAR has contributed to the relevant standards, such as EUROCAE technical specifications, incorporating new functionalities developed for the ADS-B ground station, ASTERIX interface specifications as well as to the SDPD specifications.

Shadow-mode exercises showed how the solution can be used in different types of airspace (airports, TMA, en-route) under nominal and non-nominal conditions and can be used to improve flight conformance monitoring. The solution is seen as a key enabler for surveillance infrastructure rationalisation thanks to the efficiency gains it brings in terms of costs and spectrum usage. The solution is also fully interoperable with other surveillance means.

SESAR has contributed to the relevant standards, such as EUROCAE technical specifications, incorporating new functionalities developed for the ADS-B ground station, ASTERIX interface specifications as well as to the SDPD specifications

This solution is implemented in Germany, France and Hungary and the UK.



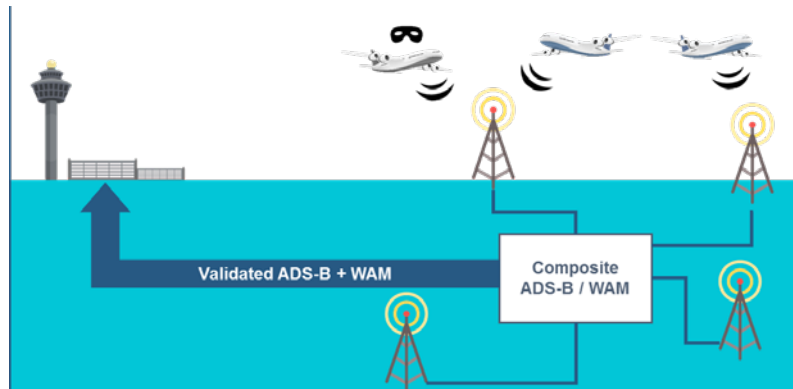


SJU References:
#114/Release 5

COMBINING SURVEILLANCE SYSTEMS FOR GREATER EFFICIENCY

Composite cooperative surveillance automatic dependent surveillance – broadcast/Wide area multilateration (ADS-B/WAM)

STAKEHOLDERS
ANSP
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BENEFITS

- Improved cost efficiency
- Improved security

Composite cooperative surveillance ADS-B/WAM is a system that exploits the similarities between the two surveillance techniques and combines them into a single system. ADS-B information received by WAM system is evaluated and if matching with WAM information extracted by others methods, then it is used in the WAM output. Information is then periodically re-evaluated.

By allowing the use of ADS-B data that has been validated against data derived in parallel by a WAM system, the system can help to reduce the number of interrogations and number of replies and therefore reduce the 1030/1090 MHz radio frequency (RF) load and improve spectrum efficiency. It achieves this through the integration of validated data items into the WAM channel, thereby preventing a need to re-interrogate the data item.

Since the two surveillance layers share hardware components, the system offers improved cost efficiency. Furthermore, the use of the system contributes to an improved security by successfully mitigating associated ADS-B threats.

Shadow-mode exercises demonstrated that use of ADS-B data in the WAM output helps to reduce the RF pollution generated by the system. Platforms were used to collect a large dataset of overlapping CAT021 ADS-B and CAT020 WAM messages and assessed to compare WAM & ADS-B values.

SESAR has contributed to the relevant standards, such as EUROCAE technical specifications for WAM and ADS-B that are implementing this 'composite' concept

This solution is implemented in Austria and the UK.





ALTERNATIVE NAVIGATION TECHNOLOGIES IN CASE OF SHORT-TERM GNSS OUTAGE

RNP1 reversion based on DME/DME

SJU references:
#PJ.14-03-04/
Release 9



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

Aircraft rely on global navigation satellite systems (GNSS) to navigate and adhere to performance-based navigation (PBN) procedures including required navigation performance 1 (RNP 1). European legislation requires all large terminal manoeuvring areas to implement RNP1 standard instrument departures and arrivals (SIDs and STARs) by 2024. In case of degradation or absence of satellite signals, aircraft revert to ground-based distance measuring equipment (DME) navigation aids in the short term to triangulate their position between ground stations.

BENEFITS

- Enhanced safety
- Improved resilience
- Worldwide interoperability

This solution supports development of updated minimum operational standards (MOPS) for terrestrial navigational aids and minimum aviation system performance standards (MASPS) to meet this alternative position, navigation and timing (A-PNT) reversion procedure to enable aircraft to fly RNP 1 routes. SESAR research found DME equipment meets reliability, integrity and continuity requirements but performance also needs to be formalised in this context in order to provide a backup for RNP 1 operations. The solution provides an acceptable means of compliance for the RNP 1 reversion based on DME/DME in all terminal manoeuvring area environments where modern DMEs are deployed. Research results are being used by EUROCAE WG 107 to update existing requirements to define new standards due delivery by end-2020. The updates include minimum integrity level specification; range accuracy requirements; and service continuity requirements. In addition, a methodology for the integrity demonstration is being defined, such that the integrity levels achieved by different OEMs can be compared and validated.

SESAR JU members and partners carried out an economic assessment for different terminal manoeuvring areas which showed positive results. While aircraft systems are not impacted by the short-term A-PNT solution, air navigation service providers may have to replace old DME systems to meet the new standards.

Although currently the implementation of RNP 1 is foreseen only to enable SIDs/STARs, the opportunity and capability to support RNP1 reversion based on DME/DME beyond the terminal area could be investigated. SESAR is also researching a number of existing and new technologies capable of supporting more demanding operational positioning and navigation requirements to meet medium and long term GNSS outages.

The solution is in accordance with Commission implementing regulation (EU) 716/2014; (EU) 2018/1048, known as the PBN IR; and EASA ED 2018/013R.

The solution is available for industrialisation and has been implemented in Lithuania and Poland.





SJU references:
#PJ.15-01/
Release 9

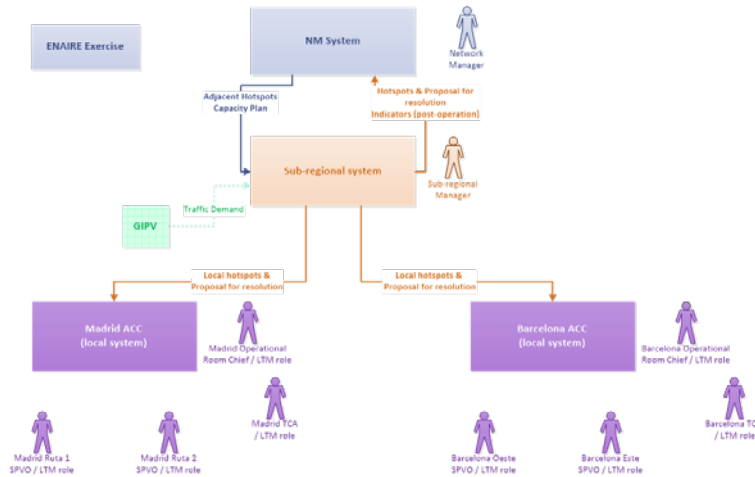
HARMONISED AIRSPACE MANAGEMENT AT LOCAL LEVEL

Sub-regional demand capacity balancing (DCB) service

- STAKEHOLDERS**
- ANSP
 - AO
 - AU
 - NM

BENEFITS

- Increased cost efficiency



The Single European Sky calls for cost-efficient services delivered in a harmonised manner, supported by open standards. Air navigation service providers (ANSPs) operate in the context of a collaborative network, using the network management function and local demand capacity balancing (DCB) capabilities to deliver efficient airspace management for civil and military airspace users.

The sub-regional demand capacity balancing (DCB) service aims to improve airspace management at sub-regional level and simplify tactical interaction between stakeholders. This common service assumes that it can optimise the operation of a highly integrated part of the network. It enables ANSPs to balance airspace demand against available capacity of the different stakeholders, while reducing workload between the region and local actors. The service is active during the whole planning phase, from up to a year before the time of operation to just before the execution phase (generally two hours before the time of active operation), within the sub-regional airspace. The primary focus is the window encompassing pre-tactical to just prior to activation. The solution is focused on the technical aspects of such service.

The solution shows the technological readiness to support exchanges between regional and sub-regional layers.

The solution can be applied by several area control centres, or several ANSPs, and supports the local traffic manager by developing plans to manage demand versus capacity within the scope of the sub-region. It uses existing operational processes and services, reorganising them to provide efficiencies, for example through the provision of a focal point for several ACCs, therefore reducing the number of point-to-point connections. The service provider collects inputs from different stakeholders about demand, capacity, military requirements and weather to determine optimal capacity balancing for the region.

Two SESAR validations showed the solution to be technically feasible: it improves cost-efficiency and can be considered as ready to move to industrialisation with some additional research into information flows, particularly the ability to feed common service data back to the regional network manager. However, the operational assumptions taken in the business model (i.e. processes, roles and responsibilities between regional/sub-regional DCB levels) are still to be validated before actual deployment. SESAR also recommends development of a standard to ensure interoperability using a common interface.

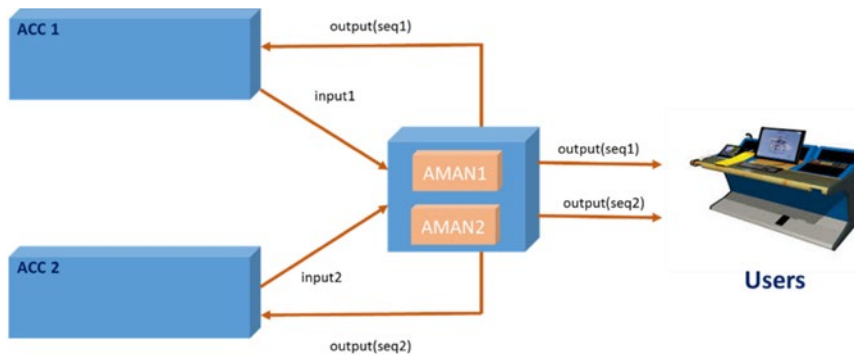
The solution is available for industrialisation.



ARRIVAL SEQUENCING BENEFITS FROM A COMMON SERVICE APPROACH

E-AMAN Service

SJU references:
#PJ.15-02/
Release 9



STAKEHOLDERS

ANSP

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BENEFITS

- Increased cost efficiency

Holding patterns close to busy airports ensure busy runways are used to full capacity. However, this results in additional fuel burn and noise emissions, often close to habitation. In response to Single European Sky cost-efficient objectives, the extended arrival management (E-AMAN) common service aims to reduce holding through earlier arrival sequencing, absorbing delay in the en-route part of the flight or even before departure of the flight in case the departure airport is located within the eligibility horizon of the E-AMAN. An optimised arrival sequence also minimises tactical intervention in the terminal manoeuvring area. The strong business case has prompted the European Commission to mandate E-AMAN implementation at 25 airports by 2024 under IR 716/2014.

E-AMAN provides arrival sequences involving multiple actors, for example multiple airport operators, arrival management systems, area control centres, upper area airspace management, as well as the Network Manager. The procedure is based on the calculation of scheduled times for runway thresholds and derived times for a coordination point and metering-fix.

The solution uses SWIM service standardisation on the example of an arrival sequence service, ED-254

SESAR JU members and partners addressed two use scenarios: By co-locating E-AMAN systems, a single common service interface can deliver services to adjacent control centres at ANSP level; while federated E-AMAN systems distribute harmonised data to regional end-users. The solution provides the technical capability to extend the arrival management process, including arrival sequencing and planning functions, and distributes this information to all involved actors using SWIM capability. The service provides local arrival planning information according to client needs and can be used in planning and tactical operations, for example providing departure delay times or for speed advisories during flight.

In a technical validation, SESAR JU members and partners demonstrated the feasibility of using the common service interface to exchange data between consumer systems from different manufacturers as stipulated in the new EUROCAE standard ED-254. It also demonstrated that clients can subscribe to arrival data from different sources. The service improves cost efficiency by reducing the number of system deployments and technical structures in operation. The solution is ready for industrialisation and has been implemented in France and Spain.



SJU references:
#PJ.15-10/
Release 9

FIRST STEP TOWARDS COMMON AERONAUTICAL DATA SERVICES

The common service for aeronautical information management

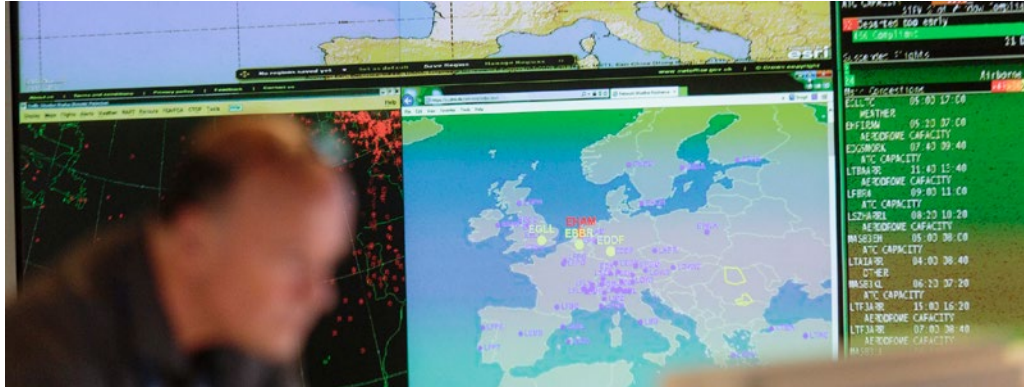
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BENEFITS

- Increased cost efficiency
- Enhanced security

Airspace users and navigation service providers use static aeronautical data to receive long term or permanent information such as PERM notice to airmen (PERM NOTAMs), as opposed to dynamic information such as the temporary closure of a runway. This solution addresses the feasibility of providing static and dynamic information in digital form at network level so that it becomes efficiently accessible as a common service to different ATM civil and military systems, reducing duplication across multiple air navigation service providers. Using a common, managed service significantly reduces the overall cost of providing AIM services instead of operating numerous individual national systems.

Implementation of the existing European AIS database (EAD) has brought optimisation, however many ATM domains cannot access the information in EAD directly yet. SESAR is supporting the evolution towards a SWIM integrated scenario in which information exchange is seamless and direct. This solution focuses on the back-end information aspects and offers full SWIM compliance. It has been validated using prototypes provided by industry partners using various architecture options and common service interfaces in a research environment.

The network-consolidated output is an AIXM-compliant dataset whose subsets can be retrieved by individual requests demanding specific geographical areas, attributes or functional features. The successful validation enables industrialisation of the solution in an operational environment, with benefits growing incrementally according to the spread of deployment of the common service. The service provides static and dynamic information in AIXM format, for example providing digital NOTAMs.

The European Commission has mandated that member states implement aeronautical information exchange among a number of ATM sub-functionalities based on initial SWIM (iSWIM) to support digital aeronautical data as an AIXM data set.

The solution relies on the AIXM/AIRM/ISRM standards and is fully SWIM compliant.

The solution is available for industrialisation and has been implemented in Latvia.





MAP-READING USING A SHARED DIGITAL SOURCE

Aeronautical digital map common service

SJU references:
#PJ.15-11/
Release 9



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

Aeronautical data provides essential information for ANSPs, airspace users and airport operators. Collecting aeronautical digital maps and providing them at network level in a highly customised format reduces the operating costs of using aeronautical maps and helps to establish a standard digital format. The aeronautical digital map common service is designed to deliver digital maps to multiple air traffic management systems which perform separation functions to meet a range of different consumer requirements.

BENEFITS

- Increased cost efficiency
- Enhanced security
- Improved safety

The service aims to provide users with the capability to retrieve graphical representations of aeronautical data, which can be easily converted to different formats such as AIXM, GML and XML etc. The output is presented as standard, harmonised, graphic information that can be retrieved by individual requests demanding specific geographical areas using regular internet protocols or through SWIM services.

Furthermore, users will only bear a cost consistent with the services they receive. Research to date also indicates the benefits will continue to grow according to the spread of deployment of the common service, with most benefits arising from Europe-wide deployment.

COSEK relies heavily on AIXM/AIRM/ISRM data exchange standards and is fully compliant with SWIM.

SESAR JU partners validated prototype services developed by industry partners in a non-operational environment using a subset of non-functional requirements and working with an ANSP. The tests confirmed the feasibility of retrieving and submitting aeronautical information using the common service and showed interoperability between different systems when handling long-term (static) data as well as dynamic (short term) information.

The solution delivers more consistent aeronautical information services across Europe and spreads the costs between ANSP customers. It also facilitates extending the services to other states not originally addressed by the EU implementing rule covering aeronautical information exchange. The benefits grow incrementally as deployment increases, improving safety due to information consistency amongst stakeholders.

The service can be deployed from a single location (centralised service) or from multiple locations (distributed service) and can be provided through outsourcing, consolidation or partnerships. The main impact is on the adaptation of interfaces of the consuming systems.

The solution is available for industrialisation and has been implemented in Latvia (partly) and Slovakia.



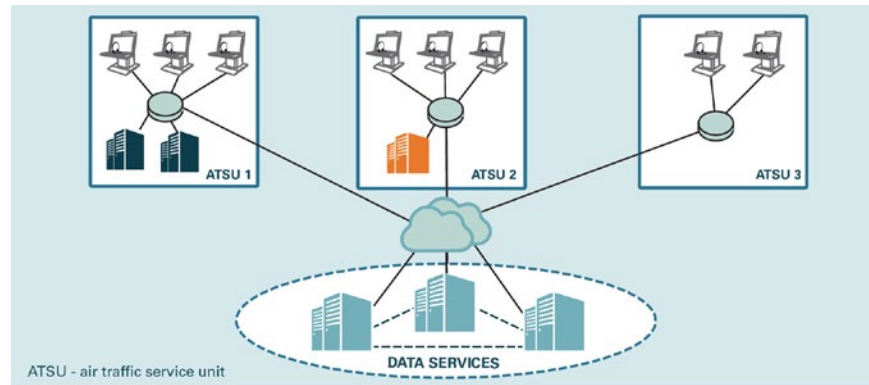


SJU references:
#PJ.16-03/
Release 9

DECOUPLING AIR TRAFFIC SERVICES FROM DATA SERVICE PROVISION

Enabling rationalisation of infrastructure using virtual centre-based technology

STAKEHOLDERS
ANSP
AO
AU
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BENEFITS

- Increased cost efficiency
- Enhanced security

Europe's air traffic management is composed of country-based systems and processes. This fragmentation or proliferation of systems results in a lack of interoperability and increases the cost of air navigation services. SESAR has developed a concept for separating the provision of air traffic services from where the data is produced. This lean and efficient use of ANSP infrastructure tackles the issues presented by fragmented European ATM systems and country-specific architectures, enabling Europe to move to an interoperable, cost-effective and flexible service provision infrastructure. By enabling increased flexibility, the ANSPs should better manage staffing for prevailing traffic conditions and ensure service continuity.

SESAR has set out the high-level system architecture to geographically decouple the ATM data service provider (ADSP) and air traffic service unit (ATSU), through service interfaces defined in service level agreements. One ATSU may use data services from multiple ADSPs, just as an ADSP may serve multiple ATSUs operating in en-route or terminal environment. The solution aims to provide increased flexibility by sharing air traffic control operations between service units, creating a more seamless airspace through the virtual centre concept. This flexibility leads to greater technical and operational agility, which in turn leads to improved performance.

SESAR partners expanded the set of use cases identified during SESAR 1, taking into account the need to safeguard safety, security and regulatory issues, and carried out technical validations using platforms from different suppliers. Among many data services selected, the tests included: voice services; flight data distribution services; flight data management; and airspace status distribution. A total of seven validation exercises addressed different aspects of the virtual centre concept.

Distribution of flight data, flight data management and coordination and transfer management services are the first three candidates to achieve sufficient level of maturity for standardisation by EUROCAE.

Service orientation is one of the pillars of the European ATM Master Plan

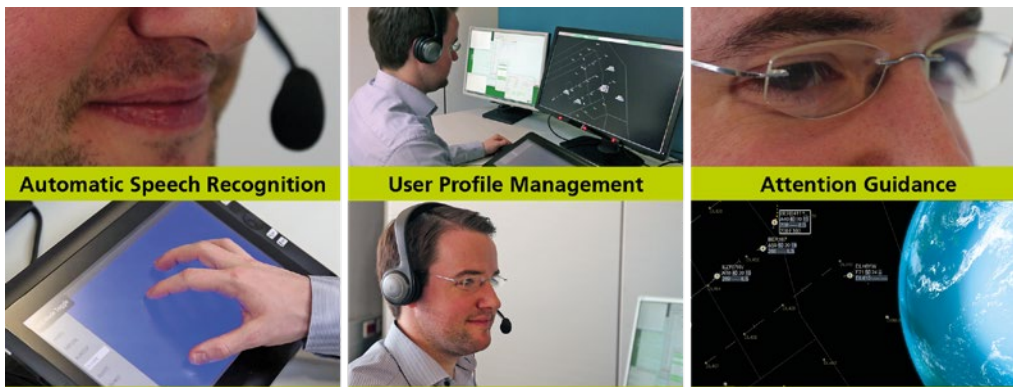
The solution is available for industrialisation.



TABLET TECHNOLOGY EASES CONTROLLER WORKLOAD IN BUSY AIRSPACE

SJU references:
#PJ.16-04-01/
Release 9

Multi-touch inputs (MTI) for the human machine interface (HMI) of the controller working position (CWP)



STAKEHOLDERS
ANSP
AO
AU
NM

Providing the human machine interface (HMI) of the controller working position (CWP) with advanced technologies can help to minimise the workload and mental strain on controllers in area control centres and towers. This is especially true when managing high density traffic or complex operations. SESAR 1 research found multi-touch functionality including handheld or tablet devices are technically mature enough to be used in the ATC/ATM environment. In addition to providing faster input methods such as 'one-touch' cleared flights, the technology supports complex tools such as map manipulation and gestures recognition to enhance usability and controller productivity.

BENEFITS

- Increased operational and cost efficiency
- Improved productivity

Touch technology already exists in some forms across a few domains in ATC, however multitouch will be able to be deployed in all domains, expanding the capabilities of particularly the approach and en-route environments. This solution builds on the results of SESAR 1 analysis to investigate the potential of multi-touch inputs. Three exercises and one technical demonstration, with air traffic controller involvement, were conducted to shed light on different aspects of multi-touch inputs in air traffic control connected to SESAR ATM master plan's flight and control phases.

Data inputs into the system by the controller are faster and more efficient

SESAR JU members and partners developed multi-touch prototypes for validation purposes. The research delivered a set of workstation solutions following a user-centred approach which demonstrated an improvement in productivity based on the measurement of human performance. The research also delivered a technical specification document. Training is an important aspect of this application and further safety evaluation is necessary, however the solution is ready to progress to industrialisation.

As multi-touch inputs represent a technological enabler and supplement or replace to existing controller input devices (like keyboard, mouse or trackball) there is no need to adapt procedures as such. The solution applies to almost the whole chain of aircraft flight phases including en-route and approach environments and enhances the controller working position.

The solution is available for industrialisation.



SJU references:
#PJ.18-04a/
Release 9

ASSURED ACCESS TO THE BEST AERONAUTICAL INFORMATION

Aeronautical dataset service

STAKEHOLDERS

ANSP

AO

AU

NM



BENEFITS

- Increased cost efficiency
- Enhanced safety and security

Aeronautical information services help airspace users, air navigation service providers and Network Manager stay up to date with aspects such as latest weather, airspace restrictions and aerodrome notices. SESAR supports information sharing using SWIM to enable data to be shared in a timely and accurate way. Providing information in digital format improves the consistency and quality of the data and enhances the exchange of information. In this solution, SESAR aims to develop a SWIM service to provide digital datasets defined by ICAO.

The service includes datasets for a specific purpose. An example is the provision of airport lighting data which is a derivation of the airport mapping dataset containing precise lighting information for a very specific purpose. The target service provider could be any aeronautical information service provider that wishes to provide their datasets in digital format and the service could be offered to any interested parties that need to consume these datasets.

The SESAR technical validation exercise of the aeronautical dataset service showed it performed functions as required. It addressed the specific case of airfield lighting data at four airports and provided 100% match with the user's requests, indicating a high quality of service. The scope and capabilities of the web service providing aeronautical dataset information is wider than in the validation context. It should provide datasets defined by ICAO Annex 15 in order to provide the benefit of having one service that is fit for all dataset needs and is ready for deployment. In a pilot exercise, the European AIS database (EAD) is drafting a plan to implement digital datasets as service based on the SESAR service definition.

The solution matches EUROCONTROL SWIM requirements and guidelines

The solution applies the principles and guidance within the framework of specifications for SWIM service description, SWIM information definition and SWIM technical infrastructure yellow profile.

The solution is available for industrialisation and has been implemented in Latvia (partly) and Slovakia.



In the pipeline

Research and innovation are underway on a further 80 candidate solutions.

These candidate solutions have been identified as enablers for optimising the airspace organisation and capacity, as well as bringing scalability and resilience to the system.

This section is very much a look at work in progress, meaning that some of these candidate solutions may not reach maturity or the end of the innovation pipeline.



**High performing
airport operations**



**Advanced air traffic
services**



**Optimised network
operations**



**Enabling aviation
infrastructure**

High-performing airport operations

The future European ATM system relies on the full integration of airports as nodes into the network. This implies enhanced airport operations, ensuring a seamless process through collaborative decision making (CDM), in both normal and adverse conditions. This feature addresses the enhancement of runway throughput, integrated surface management, airport safety nets and total airport management.



SJU ref: #PJ.02-W2-04.1



STAKEHOLDERS



SHORTER, MORE EFFICIENT ARRIVALS AND DEPARTURES FOR BUSY AIRPORTS

Advanced curved approach operation in the TMA with the use of barometric altitude

BENEFITS

- [Improved fuel efficiency](#)
- [Lower environmental impact](#)
- [Improved predictability](#)

Following more precise arrival routes helps aircraft to reduce track miles and minimise noise over built up areas. Thanks to the use of GNSS (such as Galileo), aircraft can fly RNP with accuracies of 0.3 nm or 0.1 nm, enabling airlines to fly more efficient routes and follow more flexible approach paths. Aircraft can use different alignment points to optimise procedures in terms of fuel consumption or noise abatement. By using advanced curved approach operations in the terminal area, aircraft benefit from shorter flight trajectories, increased efficiency and predictability, while reducing workload for flight crews and controllers.

This candidate solution aims to validate a system support tool for ATC, to enable mixing advanced curved approach operation, combined with legacy straight in approach operation.





SATELLITE-BASED NAVIGATION ADDS TO GREENER AVIATION FOOTPRINT

Advanced curved departure operations in the TMA

STAKEHOLDERS



Advanced navigation capabilities permit aircraft to follow more predictable, efficient flight paths, and access a wider range of departure routes. This candidate solution introduces advanced curved departure routes using more flexible standard instrument departure (SID) designs with the aim of fostering improvements in airport-airspace efficiency, flight efficiency and lowering the air traffic environmental impact (gaseous emissions and noise) by providing the means to avoid environmental constraints in the terminal area.

This is achieved through the use of more dynamic departure routes compared with today's operation.

SESAR partners are developing new SIDs designed for advanced GNSS-based procedures in the terminal area that enable airlines to fly more efficient departure routes based on curved operations rather than today's point to point routes.

The use of GNSS (such as Galileo) enable aircraft to fly RNP trajectories with high accuracies e.g. 0.3 nm. Advanced GNSS based SIDs can enhance the variety, flexibility and repeatability of departing aircraft, e.g. with an early immediate turn after departure which can allow an aircraft to depart in the desired direction. This capability can allow a more flexible SID design in single and parallel runway operations and lead to environmental improvements.

By initiating advanced curved operation after departure, new SIDs will enable more efficient terminal operations, improve runway throughput, and lower environmental impact.



BENEFITS

Improved fuel efficiency

Lower environmental impact

Improved predictability



SHORTER, MORE STABLE AND EFFICIENT ENERGY MANAGEMENT FOR ARRIVALS

Advanced curved approach operation in the TMA with the use of geometric altitude

STAKEHOLDERS



Using curved approach procedures, based on geometric altitude (GNSS-based), allow airlines to fly efficient routes in the terminal area, to conduct stable and predictable continuous descent operations independent of temperature (Improved productivity among flight crew and ATC). This will contribute to increased efficiency, predictability and lowered environmental impact.

This candidate solution aims to validate the use of GNSS-geometric guidance after the initial approach fix, which offers opportunities for optimised three-dimensional approach operations with enhanced aircraft energy management in order to make the transition to the final approach phase easier in any weather conditions, which might affect today's barometric vertical navigation. It requires developing and validating a concept that



enables controllers to ensure that safe vertical separation is maintained between all traffic, whether they are using geometric or barometric vertical navigation.

BENEFITS

Improved fuel efficiency

Lower environmental impact

Improved predictability



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

ALTERNATIVE TOUCH-DOWN POINT REDUCES NOISE AND RAISES RUNWAY CAPACITY

Second runway aiming points (SRAP)

BENEFITS

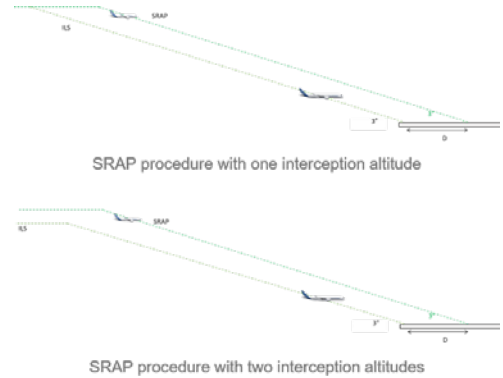
Reduced environmental impact

Increased runway throughput

Enhanced satellite-based navigation systems such as satellite-based augmentation system (SBAS) and ground-based augmentation system (GBAS) unlock the potential for airspace users to follow more precise flight paths and take advantage of flexible arrival procedures at busy airports.

This candidate solution introduces a second runway aiming point (SRAP) as a new concept of operations. SRAP is a new enhanced arrival procedure (EAP) that improves runway performance by using two active thresholds on a single runway and may make use of GBAS or SBAS navigation systems. In doing so, the candidate solution enables inbound aircraft to reduce fuel use and noise footprint impact in areas surrounding the airport. It can also lead to reduced runway occupancy time and/or taxi-in time, while also allowing increased capacity as a result of optimised wake separations.

The SRAP concept is a published approach procedure that enables aircraft to land on a second aiming point located further down the runway created with associated runway ground markers,



lights and visual aids. The glide slope for the SRAP procedure operates in parallel to the nominal one operated for the first aiming point.

Choosing a SRAP approach (over the conventional one) is the result of the best compromise between available runway length, preferential runway exit use, noise, wake turbulence separation constraints, and the runway occupancy time.



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

STEEPER DESCENTS REDUCE NOISE FOOTPRINT

Increased glide slope (IGS)

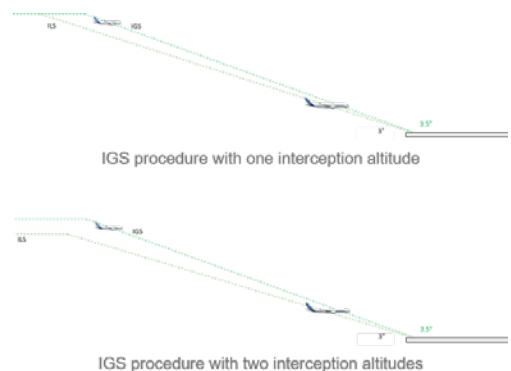
BENEFITS

Reduced environmental impact

Implementation of satellite-based augmentation systems (SBAS) and ground-based augmentation systems (GBAS) enable airspace users to follow more flexible flight paths. Introducing more flexible arrival routes can reduce the amount of noise at ground level near the final approach segment.

SESAR research is looking at increasing the glide slope so that aircraft equipped with enhanced navigation capability can use augmented satellite signals to fly steeper approach paths. This candidate solution introduces the increased glide slope as a new concept of operation. The enhanced arrival procedure (EAP) reduces environmental impact by the use of two glide slopes active simultaneously, where aircraft flying on the higher slope generate less noise.

The procedures feature a glide slope between the published one (commonly 3°) and 4.49° (limit above which the steep approach concept applies), and provide a significant reduction in ground



noise level to an order of magnitude of 3 dBA in approaches between 15 NM and 4 NM from the runway threshold.



STEEPER DESCENT AND DISPLACED THRESHOLD REDUCES NOISE AND INCREASES THROUGHPUT

Increased glide slope to a second runway aiming point (IGS-to-SRAP)

More precise management of arrival patterns surrounding an airport can have a big impact on the noise footprint. This candidate solution introduces a new concept of operations that increases the glide slope to a second runway aiming point (IGS-to-SRAP) to reduce the amount of noise at ground level. The new enhanced arrival procedure (EAP) enhances performance by using two active thresholds on a single runway and an increased glide slope to the second one, and may make use of satellite navigation and augmentation capabilities, such as Ground-Based Augmentation System (GBAS) and Satellite-Based Augmentation System (SBAS).

The procedure applies an increased glide slope, above the approach angle for the existing runway threshold and up to 4.49°, to an aiming point further down the runway threshold. The published procedure enables inbound aircraft to reduce noise footprint and possibly reduce runway occupancy time and/or taxi-in time depending on local runway/taxiway layout.

Unlike the increased glide slope concept (which applies to the runway physical threshold), increasing the glide slope on an additional (second) runway aiming point should prevent a potential reduction of airport capacity and may increase capacity through optimised wake turbulence separations.

The candidate solution also offers additional benefits over the second runway aiming point concept (SRAP), where the slope angle remains unchanged, IGS-to-SRAP enables a further reduction of noise impact and wake turbulence separations for an equivalent displacement of the additional runway aiming point.

STAKEHOLDERS



BENEFITS

Reduced environmental impact

Increased runway throughput



BIG DATA HELPS PREDICT FLIGHT ARRIVALS WITH GREATER ACCURACY

Enhanced optimised runway delivery for arrivals (eORD)

Airport arrivals can become constrained as a result of wake vortex separations, wind conditions and high runway occupancy. SESAR is developing a more efficient separation delivery tool for arrivals to support complex separation rules at capacity-constrained airports.

The enhanced optimised runway delivery (eORD) tool is based on more accurate predictions of final approach speed profiles derived from advanced machine learning (ML) techniques. eORD may also benefit from advanced meteorological sources, including SWIM METforWTS service, to gain more accurate and reliable wind nowcasts and forecasts on the final approach which could also be used to better predict aircraft speed profiles.

The more accurate predictions of final approach speed profiles will be used to more accurately determine the spacing that needs to be delivered at the deceleration fix (DF) in order to achieve the



required separation/spacing at the separation delivery point.

This more accurate spacing and separation delivery will lead to further reduced spacing between consecutive arrivals for the majority of aircraft pairs. Overall, the eORD tool will lead to a benefit in terms of increased runway throughput capacity due to the reduced, optimised spacing on the final approach. As the spacings are based on more accurate aircraft behaviour/performance and as a result are better tailored per aircraft pair, there is a potential positive impact on safety.

STAKEHOLDERS



BENEFITS

Increased runway throughput

Potential positive impact on safety



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

REAL-TIME DATA UNLOCKS DYNAMIC SPACING BETWEEN ARRIVALS

Dynamic pairwise separations for arrivals (D-PWS arrivals)

BENEFITS

Increased runway throughput



In busy arrival streams, aircraft remain safely separated to avoid encountering wake turbulence from preceding aircraft. SESAR is researching ways of optimising wake separations between consecutive arrivals on the final approach by

using dynamic real-time data, big data and machine learning techniques.

The candidate solution allows for the conditional reduction of wake separations based on wake risk predictions. Wake risk predictions are based on the real time measurements of wake turbulence from using a ground based lidar, metrological data and aircraft data combined with advanced big data and machine learning techniques.

The dynamic pairwise wake separations per aircraft pair are relayed to the tower controllers via a separation delivery tool. These dynamic pairwise wake separations lead to a benefit in terms of increased runway throughput capacity due to the reduced, optimised separations on the final approach, and safety is maintained.



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

BIG DATA GUIDES MORE EFFICIENT, SAFE AIRCRAFT DEPARTURES

Enhanced optimal spacing delivery for departures (eOSD)

BENEFITS

Increased runway throughput

Capacity-constrained airports rely on complex separation rules to ensure aircraft depart safely and avoid wake turbulence. The enhanced optimised spacing delivery for departures solution builds on the work done on optimised spacing delivery in SESAR wave 1 (PJ.02-01-02) to develop a more accurate and efficient delivery tool to support the implementation of complex separation rules in capacity constrained airport environments.

The enhanced optimised spacing delivery (eOSD) tool improves the efficiency of spacing delivery between consecutive departures by using big data and machine learning techniques to calculate more accurate predictions of aircraft behaviour, such as rolling distance/rotation point, departure speed/climb profile and predicted trajectories. eOSD may also benefit from advanced meteorological sources, including the SWIM METforWTS service, to gain more accurate and reliable wind nowcasts and forecasts on the initial departure path.



This more accurate spacing/separation delivery will lead to further reduced spacing between consecutive arrivals for the majority of aircraft pairs.

Overall, the enhanced optimised spacing delivery for departures solution will lead to a benefit in terms of increased runway throughput capacity due to the reduced, optimised spacing between departures. As spacing is based on more flight specific behaviour/performance and as a result are better tailored per aircraft pair, there is a potential positive impact on safety.



DYNAMIC REAL-TIME DATA HELPS TOWER CONTROLLERS INCREASE RUNWAY CAPACITY

Dynamic pairwise separations for departures (D-PWS-D)

Introducing more efficient departure operations can help to increase throughput at capacity-constrained airports. SESAR is looking at ways to define a reduction in wake separations for a following aircraft between consecutive departures using dynamic real-time data.



The research addresses two main threads. The first thread considers a departure procedure where the follower aircraft employs an earlier differentiated rotation position and a steeper climb profile over the straight-out initial departure path than preceding heavier aircraft, avoiding a potential wake turbulence encounter. The second thread makes use of big data and machine learning techniques combined with real-time measurements of wake turbulence using a ground-based lidar, MET data and aircraft data to predict wake risk.

In both cases the dynamic pairwise wake separations per aircraft pair are relayed to the tower controllers via a separation delivery tool.

These dynamic pairwise wake separations lead to a benefit in terms of increased runway throughput capacity due to the reduced, optimised separations between departing aircraft, and safety is maintained.

STAKEHOLDERS



BENEFITS

Increased runway throughput



MACHINE LEARNING HELPS RAISE CAPACITY FOR ARRIVALS

Dynamic pairwise runway separations based on ground-computed arrival ROT (D-PWS-AROT)

Wake turbulence separations ensure aircraft always remain within a safe operating envelope during approach and on the runway. At large and very large airports aircraft arrivals and their runway occupancy time (ROT) play a key part in determining airport capacity. SESAR research into arrival runway occupancy time (AROT) aims to improve prediction of AROT and runway exit, increasing airport efficiency and safety.

Through the development and deployment of enhanced runway throughput concepts based on wake separation reduction, SESAR is addressing simultaneously constraints caused by runway occupancy times and safety issues arising from related congestion. The concept is based on runway occupancy categorisation (ROCAT) criteria developed in SESAR wave 1 PJ.02-08-03 and as part of the Horizon 2020 SafeClouds project.

The candidate solution uses big data and machine learning techniques to develop more accurate predictions of AROT and runway exit based on aircraft characteristics such as aircraft type, weight, equipage and weather. The data is expected to

improve offline analysis, together with continuous monitoring and improvement of the quality of AROT predictions during operations. Thanks to machine learning, the more accurate ROT predictions of the leader allows the controller to apply a reduction of the spacing using the optimised runway delivery (ORD) tool.

Dynamic pairwise runway separation for arrivals based on ground-computed AROT is expected to increase runway throughput capacity and resilience, by optimising separation/spacing on the final approach with potential positive impact on safety thanks to an accurate prediction of the runway exit.

STAKEHOLDERS



BENEFITS

Increased runway throughput

Improved resilience

Potential for enhanced safety





STAKEHOLDERS

- ANSP
- AO
- AU
- NM

DOWNLINKED REAL-TIME ARRIVAL DATA IMPROVES RUNWAY EFFICIENCY

Dynamic pairwise runway separations for arrivals (based on A/G data exchange)

BENEFITS

Increased runway throughput

Runway capacity is a limiting factor at many European hub airports, and expansion programmes are frequently hampered by lengthy and unpopular review processes. Looking at alternative measures, SESAR partners are researching technical, procedural and performance aspects of runway operations to improve the efficiency and resilience of capacity constrained airports.

The scope of this candidate solution includes the development of arrival runway occupancy time (AROT) airborne predictions which are downlinked to air traffic control ahead of touchdown during the descent phase. The predictions take into consideration the performance characteristics of the aircraft, its weight and braking capability, the selected runway exit, atmospheric conditions, wind strength and direction, and the condition of the runway. The AROT is automatically predicted on-board the aircraft in real-time and then shared with the ground controller to deliver more accurate separation management for consecutive aircraft.

The candidate solution targets capacity constrained runways during high intensity runway operations and applies to very large, large and possibly medium airports. Expected benefits include an increase in runway throughput thanks to a reduction in approach separation due to a more accurate prediction of the runway occupancy time.



STAKEHOLDERS

- ANSP
- AO
- AU
- NM

COCKPIT INTELLIGENCE DELIVERS SAFER, HIGHER CAPACITY ARRIVAL STREAMS

Delegation of arrival separation to the flight crew

BENEFITS

Increased runway throughput
Enhanced safety

At capacity constrained airports, traffic demand for runway operations can exceed the runway capacity. Airports are looking at ways to improve runway efficiency, especially under adverse weather conditions, by optimising wake turbulence separation between consecutive aircraft.

This SESAR candidate solution builds on work completed in SESAR1 (solution #16) and SESAR 2020 wave 1 (PJ.01-05) developing time-based separation between consecutive arrivals.

The latest research investigates the delegation of responsibility for separation from air traffic control to the flight crew under instrument flight rules (IFR) conditions. It then becomes the role of the flight crew to apply and maintain the applicable wake turbulence separation with the previous aircraft until touchdown. This is carried out using the avionics capabilities and indicators in the cockpit to monitor and maintain the procedure.

The process is expected to contribute to enhanced runway throughput through the use of dynamic data and achieve more accurate separations than those delivered based on separation support-to-ATC tools such as the optimised runway delivery (ORD) tool. There is an additional safety benefit as the procedure would avoid separation falling below the minimum required separation between a specific pair.





ENHANCED WEATHER DATA BRINGS MORE PREDICTABLE RUNWAY OPERATIONS

MET data service for wake turbulence separation

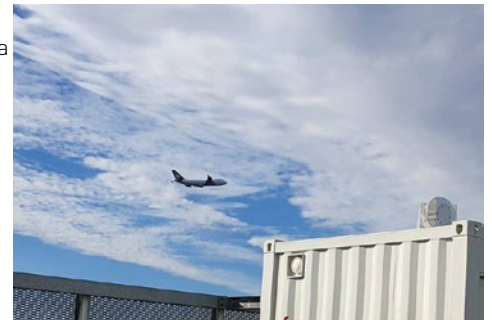
Using advanced separation techniques, such as time-based, weather dependent or pairwise separation between aircraft arriving or departing the airport, improves runway throughput, which is particularly beneficial at congested airports. Tailored wind and weather information offers further capacity benefit when combined with newly developed ATM tools.

The meteorology for wake turbulence separation (METForWTS) technological candidate solution uses enhanced weather products to provide wind profiles along the glide and departure paths to three nautical miles and beyond. It uses SWIM data exchange and a specially developed algorithm to process sensor inputs from the four-dimensional weather cube (4DWxCube).

As standalone wind sensors experience limitations, additional sensor capabilities or extrapolation techniques are needed. For

example, Doppler radar only provide, data in wet conditions while Doppler Lidar provides a limited wind profile, since commercially available wind lidars have difficulty in measuring wind much beyond 10 km. It is for this reason that SESAR researchers are looking at novel techniques like machine learning algorithms for lidar data integration with aircraft in situ measurements.

The technological candidate solution aims to define the data model for the enhanced wind products that are needed for the SWIM service METForWTS, and to examine how they will be integrated into controller tools for optimised separation delivery (OSD) and optimised runway delivery (ORD).



BENEFITS

Increased runway throughput

Improved resilience

STAKEHOLDERS



ALTERNATIVE SENSORS HELP SECONDARY AIRPORTS OPERATE IN LOW VISIBILITY

Improved capacity and safety of runway operations at secondary airports in low-visibility conditions

Small and medium sized airports need cost-efficient solutions to perform operations in low-visibility conditions. While advanced equipment (e.g. A-SMGCS) and services are widely available, the cost of installation and maintenance may exceed the financial capability of secondary airports. Introducing low-cost solutions can bring direct benefits and lead to increased resilience at primary airports by reducing the number of flight deviations.

SESAR is exploring alternative methods of ground surveillance capable of tracking aircraft and vehicles in meteorological conditions below CAT I at secondary airports to enhance operations in low-visibility conditions. This candidate solution evaluates different options for aircraft and vehicle tracking using camera-based systems as an affordable alternative surveillance source, or in combination with other available surveillance sources such as multilateration and automatic dependent surveillance – broadcast (ADS-B) sensors. The research includes an assessment of

the level of required infrastructure, the relevant services and procedures needed to benefit from the new capabilities, a review of new technologies involved, and the particular context of secondary airports with limited demand.

The intention is to enable all airport stakeholders to use the video data as a tool to enhance safety and operational performance and benefit from the new capabilities.

The candidate solution is expected to improve predictability, resilience and safety in adverse weather conditions at less equipped aerodromes, thanks to cost-efficient technologies and supported by adapted procedures.



SJU ref: #PJ.02-W2-17.1, formerly part of #PJ.02-06-W1

STAKEHOLDERS



BENEFITS

Increased resilience

Improved predictability

Enhanced safety

SJU ref: #PJ.02-W2-17.2,
formerly part of
#PJ.02-06-W1

STAKEHOLDERS



SECONDARY AIRPORTS FIND NEW WAYS TO OPERATE IN LOW-VISIBILITY CONDITIONS

Improved approach procedures into secondary airports in low-visibility conditions

BENEFITS

- Increased safety
- Improved resilience
- Improved predictability
- Increased fuel efficiency



The lack of appropriate navigation systems at secondary airports means that normally they are unable to support low visibility procedures (LVP) in conditions below CAT I, and approaching traffic has to divert to a larger airport. Where

conventional navigation and surveillance systems cannot be considered because of capital limitations, new airborne technologies are being researched to enable instrument approach procedures in low-visibility conditions.

This technological solution focuses on means of lowering the decision height through development and validation of airborne navigation capability allowing approach down to LPV-100/ CAT II minimums. LPV-100 operations shall be supported by systems that do not involve major airport and ANSP capital investments.

The Solution is enabled by enhanced positioning for localiser performance with vertical guidance (LPV) approach based on single constellation single frequency space-based augmentation system (SBAS) with additional aiding sensors.

SJU ref: #PJ.02-W2-17.3,
formerly part of
#PJ.03b-01-W1

STAKEHOLDERS



ALERTING CONTROLLERS TO POTENTIAL CONFLICTS AT SECONDARY AIRPORTS

Airport safety nets for controllers at secondary airports

BENEFITS

- Improved safety

Safety is aviation's top priority. To ensure even safer airports, this candidate solution sets out to mitigate the risks of runway incursion and more generally the risk of incidents and accidents involving aircraft at the airport. Different, innovative types of controller alerts are being developed targeting secondary airports without A-SMGCS or where there is no alerting capability.

The candidate solution takes account of new surveillance capabilities such as ADS-B, in combination with appropriate non-cooperative sensors, e.g. extremely high frequency devices, to trigger controller alerts for incursions on the runways or conflicting situations on the airport surface in general. Video-based surveillance is used to improve situational awareness by identifying potential conflicts and decreasing the number of false alarms.

The solution aims to provide secondary airports with additional procedures to those currently available, for example reduced movements during low visibility conditions or at night or



applying a single aircraft procedure. The safety nets serve to highlight areas where higher attention is needed and provide appropriate alerts to controllers. Safety is improved as a result of detection of potential and actual conflicting situations involving mobile and stationary traffic on runways, taxiways and apron/stand/gate areas, based on the available infrastructure and operational environment.



ENHANCED AND SYNTHETIC VISION TO EXPAND ACCESSIBILITY OF AIRPORTS

Equivalent visual approach and landing operations providing improved resilience to LVC

Medium and small airfields have limited resources to invest in advanced ground infrastructure to support all weather operations. Emerging vision-based technologies offer an alternative, which is located on board the aircraft, uses existing infrastructure and published instrument approach procedures (IAP) and can be used by all aircraft types.

SESAR research is continuing the development of enhanced flight vision systems (EFVS) by introducing them into large commercial aircraft and by investigating advanced solutions on business jets or regional aircraft such as the Synthetic vision guidance systems (SVGS) concept, or CVS using advanced active sensors that offer enhanced penetrability in adverse conditions, potentially used in combination with SVGS. These additional capabilities will increase the performance and reliability of EFVS landing operations. In doing so, the candidate solution will enable business aviation, regional as well as commercial airspace users to access all

airport types – including secondary airports – possibly in all weather conditions. This reduces cancellations, diversions and delays where the aerodrome has been declared suitable for EFVS operations.

The solution scope includes the development and validation of these vision systems to allow to operate beyond published minimum (DA/H, RVR), including in low-visibility conditions. It considers their use with 3D instrument approaches, such as satellite-based augmentation system (SBAS) CAT 1, ILS CAT I or ground based augmentation system (GBAS) GAST-C guidance signals to support approach and landing operation in most of adverse weather situations where CAT II/III instrument landing system (ILS) would otherwise be necessary.

SJU ref: #PJ.02-W2-17.4,
formerly part of
#PJ.03a-04-W1

STAKEHOLDERS



BENEFITS

Increase accessibility

Enhanced safety

Increased resilience

Improved predictability



MORE DETAILED CONTROLLER ALERTS BOOST AIRPORT SAFETY

Extended airport safety nets for controllers at A-SMGCS airports



Advanced surface movement guidance and control systems (A-SMGCS) are used to track aircraft and vehicles at busy airfields and alert controllers about potential conflicts. To ensure even safer airports, this candidate solution sets out to mitigate the risks of runway incursion and more generally the risk of incidents and accidents involving aircraft at the airport with the help of additional, innovative types of controller alerts.

SESAR is looking at how new generation automation tools can offer improved conflicting ATC clearances (CATC) and conformance

monitoring (CMAC) alerting functions for controllers. The research extends both functions to cover the entire airport as additional applications on top of the use of CMAC/CATC alerts deployed as part of SESAR 1 solution #02 'Airport safety nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances', together with the A-SMGCS routing & planning services. The controller tools serve to maximise situational awareness and to highlight areas where higher attention is needed through appropriate predictive indications and controller alerts.

The candidate solution also addresses the challenges of integrating different safety nets - and controller alerts - including those delivered in earlier SESAR Solutions.

Solution benefits are expected in safety gain on the airport surface and in human performance improvements for tower controllers (improved situational awareness and reduced workload) by reducing the number of airport surface incidents at main airports with A-SMGCS.

SJU ref: #PJ.02-W2-21.1,
formerly part of
#PJ.03b-01-W1

STAKEHOLDERS



BENEFITS

Enhanced safety

Improved human performance

SJU ref: PJ.02-W2-21.2,
formerly part of PJ.03a-01-W1



STAKEHOLDERS



A MOVING MAP IMPROVES VEHICLE DRIVER AWARENESS

Enhanced guidance assistance to airport vehicle driver combined with routing

BENEFITS

Enhanced safety

Improved efficiency

Reduced visibility on the airport surface impacts the safety and efficiency of vehicles operating in both the apron and manoeuvring area. The high-level objective for this candidate solution is to increase vehicle drivers' situational awareness by providing them with supplementary guidance means in all weather conditions.

The solution includes the provision, via the routing and guidance service, of enhanced guidance assistance. Dynamic traffic context information including status of runways and taxiways, obstacles and route is displayed to the vehicle driver by application of an airport moving map and guidance is automatically shown as a graphical path to be followed.

The expected benefits include a more comfortable and expedite driving experience

for vehicle drivers in both the apron and manoeuvring area. Safety will benefit from the visual information shown to the driver, which is supplementary to voice communication.



SJU ref: PJ.02-W2-21.3,
formerly part of #PJ.03a-01-W1



STAKEHOLDERS



DATALINK ADDS SAFETY AND EFFICIENCY TO VEHICLE OPERATIONS

Airport ATC provision of ground-related clearances and information to vehicle drivers via datalink

BENEFITS

Enhanced safety

Improved human performance

Vehicle movements at the airport entail a wide range of operations in support of safe and efficient execution of ground airside operations including runway and taxiway inspection, towing of aircraft, follow-me, emergency, cleaning, catering, fuelling, baggage handling. These operations on the apron and manoeuvring area stand to benefit from automated exchange between vehicle drivers and tower controllers using datalink for ground-related clearances and information.

This candidate solution addresses improved situational awareness as a result of electronic communications between tower controllers and vehicle drivers. Datalink exchange reduces possible misunderstandings and ambiguities in the provisioning of clearances and requests from either side of the communication compared to clearances and information given by voice, thus increasing safety.

The tower controller has constant awareness of all the contacts and requests received via datalink, while the vehicle drivers have constant visual access to all the clearances in a digital format. Time critical instructions referring to operations occurring close to/on runways are handled via voice, while other communications can be handled via both datalink and voice, according to procedures defined locally at the airport.

Expected benefits include a facilitation of the tower controller's work while maintaining the level of safety with increasing traffic.





SJU ref: PJ.02-W2-21.4,
formerly part of
#PJ.03a-01-W1

AUTOMATED SURFACE MOVEMENT GUIDANCE AROUND THE CLOCK

Full guidance assistance to mobiles using 'follow the greens' procedures based on airfield ground lighting (aprons/taxiways/runways)

STAKEHOLDERS

ANSP	AO	AU	NM
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Maintaining efficient and predictable aircraft movement between stand to runway in all weather conditions is a challenge at busy airports, but there are tools available which can help to guide aircraft safely around the airfield. The 'follow the greens' candidate solution receives the cleared route provided by the solution, and confirmed by the tower controller and illuminates the taxiway centreline lights to a specified distance ahead of the aircraft under guidance by switching them on and off automatically, and also, where applicable, switching stop bars on and off automatically.

The airfield ground lighting guidance takes into account tactical decisions made by the apron manager, ground and runway controllers, in addition to surface management constraints. The candidate solution is capable of automatically supporting safe spacing between moving aircraft and managing priorities between aircraft on the

aerodrome surface in all weather conditions. Priorities between multiple aircraft are based on local operating rules such as runway exit versus parallel taxiways, aircraft versus vehicle, aircraft converging or crossing at intersections, and taxiways passing close to push back routes or other taxiways where insufficient wingtip separation exists.

The airfield lighting guidance is available on a 24/7 basis in all weather conditions and on the entire movement area. Since the airfield ground lighting technology is expensive, the candidate solution applies predominantly to larger airports.

BENEFITS

- Enhanced safety
- Improved predictability
- Improved human performance



SJU ref: PJ.02-W2-21.5,
formerly part of
#PJ.03a-01-W1

RELIABLE SURFACE GUIDANCE WHATEVER THE WEATHER

Enhanced safety in LVP through use of dynamic virtual block control

STAKEHOLDERS

ANSP	AO	AU	NM
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Low visibility conditions call for enhanced safety measures to maintain throughput levels safely at busy airports. This candidate solution builds on the virtual block control solution developed in SESAR 1 through the use of real stop bars and virtual stop bars appropriately placed in the manoeuvring and movement areas, for example at busy crossing points. It enables the ground

controller to reduce the size of control blocks while ensuring a safe longitudinal spacing is guaranteed between taxiing aircraft or taxiing aircraft and vehicles in low visibility conditions (when ATC is in charge of providing a safe longitudinal spacing among taxiing traffic). The application D-VBC contributes to smoother and more predictable traffic flow during low visibility conditions.

The candidate solution relies on an A-SMGCS surveillance solution as well as taxiway routing and route monitoring. Tower controllers select the clearance limit at a virtual stop bar position for an aircraft under control and communicate the clearance via radio, or optionally via datalink (D-TAXI) enabling the D-TAXI route to be displayed in the cockpit. The assigned VSB position and the guidance information become active when cleared by the controller. The candidate solution also looks a fully dynamic virtual block control (FD-VBC) where dynamic VSB positions that can be assigned more or less arbitrarily.

BENEFITS

- Enhanced safety
- Improved predictability
- Improved human performance

SJU ref: PJ.02-W2-21.6,
formerly part of
#PJ.03a-01-W1



STAKEHOLDERS



ADVANCED AUTOMATED ASSISTANCE TO CONTROLLER FOR SURFACE MOVEMENT PLANNING AND ROUTING

Surface route planning and management operations

BENEFITS

- Increased efficiency
- Improved predictability
- Improved human performance

Airport surface movement guidance and control systems (A-SMGCS) are key to reaching a high level of predictability of operations on the airport surface. Routes and taxi times calculated by the A-SMGCS routing service determine the ground segment of the aircraft business trajectory.

This candidate solution's objective is to enhance the A-SMGCS Routing Service by allowing the controller the possibility to introduce, in an interactive and graphical way, tactical operational constraint (such as taxiway closures) and adapting the route calculation accordingly. Furthermore, in case of innocuous route deviations by any mobile, the Routing Service is enhanced with automatic recalculation of a new best route, therefore expediting the process of managing traffic on the airport surface especially in congested situations.

The concept varies from the A-SMGCS routing function delivered in SESAR 1 by introducing a continuous on-line de-conflicting A-SMGCS routing function in real-time. The routing system

detects conflicts as soon as they arise and flags them to the controller with suggestions for resolution. A new route can be accepted or handled manually and becomes an integrated part of the routing function.

The candidate solution is expected to lead to a more efficient airport resource allocation with a positive impact on predictability in terms of reduced variability of surface operations and less human intervention to manage traffic conflicts in the short-term planning and tactical phases.



SJU ref: PJ.02-W2-25.1,
formerly part of Solution
#PJ.03b-06 in Wave 1



STAKEHOLDERS



GROUND AND AIRBORNE SENSORS IMPROVING RUNWAY CONDITION MONITORING

Enhanced runway condition awareness for runway excursion prevention

BENEFITS

- Enhanced safety
- Improved resilience

Runway excursions account for nearly a quarter of all runway safety accidents, according to IATA. This candidate solution aims to improve the assessment of runway surface contamination and global awareness in order to prevent runway excursions during take-off and landing.

The candidate solution is developing a runway condition awareness and monitoring system (RCAMS) to support airport duty officers in facilitating continuous runway condition awareness. Built-in runway sensors and a dedicated runway condition model are the core elements of this system, which are also fed by auxiliary surveillance data. RCAMS is delivering a dedicated interface for duty

officers equipped with both appropriate alerts and assistance in rapid runway condition report (RCR) dissemination to critical stakeholders (e.g. ATC). RCAMS is fully compatible with the global reporting format (GRF) recently introduced by ICAO. RCAMS also includes tower ATCO/APP ATCO interface that is networked directly with duty officer. This approach makes rapid runway condition dissemination to key stakeholders easier and more robust.

The ground-based system is supported by an on-board braking action computation system (OBACS), which estimates the runway condition during the landing roll. The resulting measurements are pushed automatically to RCAMS interface allowing for subsequent alerts to the duty officer if needed. OBACS output can also be used independently by the flight crew for pilot report (PIREP) assistance.

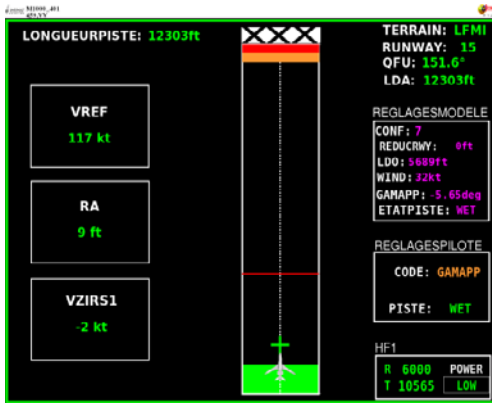




ALERTING THE FLIGHT CREW TO CURRENT SURFACE CONDITIONS

Support tools for pilots for better prevention of runway excursions and monitoring of A/C trajectory

As much as controllers and duty officers need support tools to prevent runway excursions, flight crews too need to be aware of and alerted to



surface conditions and potential risks. With this in mind, this candidate solution aims to reduce the risk of runway excursion during take-off or landing thanks to a support and alert on-board system.

The take-off monitoring system integrates runway surface condition information to provide more accurate alerts to the flight crew in case of detected risk of runway excursion during the take-off phase.

The aircraft trajectory monitoring system uses computer vision to provide the flight crew with an enhanced awareness of runway/taxiway excursion risk and collision threat.

SJU ref: PJ.02-W2-25.2, formerly part of *PJ.03b-06 in Wave 1

STAKEHOLDERS



BENEFITS

Enhanced safety



CONNECTED REGIONAL AIRPORTS

Low-cost integration of smaller airports into the network

Airports can be integrated into the air traffic management network by departure planning information (DPI) messages to the Network Manager. On the one hand, large airports can implement airport collaborative decision making (A-CDM), which improves the information exchange with the network manager (NM) by sharing the status and time estimates of their outbound flights. On the other hand, smaller airports can implement the advanced ATC tower concept, allowing them to send a DPI message to the NMOC when an aircraft leaves the blocks. Regional airports not ready to invest in the full A-CDM suite but willing to share more than what is offered by the advanced ATC tower concept with the NMOC benefit from a third candidate solution using a reduced set of CDM milestones to deliver quasi-automatic messages to the network reducing the need for airline/ground handler inputs.

Regional airports have an impact on the network and the sharing of accurate estimates of take-off times for flights from such airports could bring network performance benefits as a result of enhanced traffic predictability and reduced need for sector capacity 'buffers'. The connected regional network solution introduces a simplified approach based on a reduced set of event-driven – rather

than time-driven – turnaround milestones. The milestones are generated in a quasi-automatic manner and offer a full set of DPI messages to the NMOC.

The connected regional airports candidate solution improves the efficiency of the turnaround process at the airport as a result of the process of information sharing, with CDM partners able to access key milestones for each flight. The concept provides regional airports with an affordable means of achieving the Network Manager accuracy criteria.

SJU ref: PJ.04-W2-28.1, formerly part of PJ.04-01-W1

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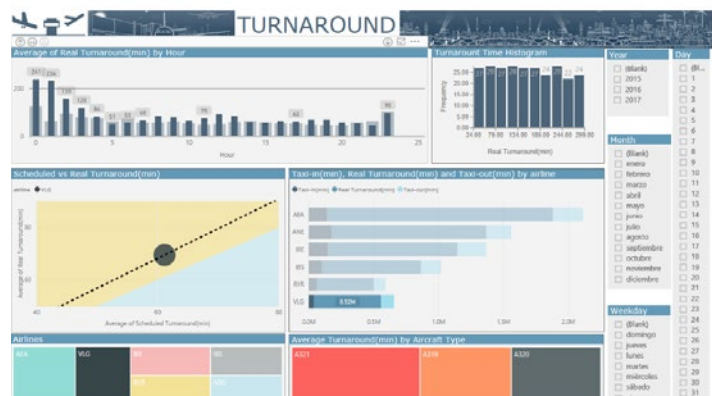


BENEFITS

Improved efficiency

Added flexibility

Improved predictability



SJU ref: PJ.04-W2-28.2,
formerly part of PJ.04-01-W1



STAKEHOLDERS



LOW COST, DECENTRALISED AIRPORT COORDINATION

Collaborative management at regional airports

BENEFITS

Enhanced efficiency

Improved resilience

Improved predictability

The introduction of a centralised, multi-stakeholder command and control facility such as the airport operations centre (APOC) developed by SESAR 1 and the first wave of SESAR 2020 are shown to improve airport resilience in large airports.

Regional airports lack the same level of resources however still have an important impact on overall network performance.

This candidate solution, devoted to regional airports, considers the benefits of a lite-APOC for regional airports based on enhanced process automation (including machine learning techniques) and innovative approaches to information sharing including through a more decentralised approach.

Cost efficiency is one of the main drivers behind this concept as it strives to deliver the benefits of APOC to all types of airports. Until now APOC implementations have focused on physical deployment of a multi-stakeholder facility to foster cooperation and information sharing. The need to extend the benefits to regional airports makes it necessary to study other, more innovative approaches to an APOC deployment based on new technologies and methodologies, such as increased levels of automation and information sharing.



SJU ref: PJ.04-W2-28.3,
formerly PJ.04-01-W1



STAKEHOLDERS



DATA EXCHANGE STANDARDS MINIMISE NETWORK DISRUPTION

Connected large airports

BENEFITS

Enhanced efficiency

Added flexibility

Improved predictability

Improved airport resilience

As large airports have a major impact on the performance of the whole network, sharing information during normal operations and in severe disruption scenarios helps to manage traffic flow and benefits from common standards of data exchange. Standards development under SESAR 1 needs to be finalised to create a European standard.

Sharing information in the airport operations plan (AOP) is necessary to create a complete picture of expected flight events and their impact on the network. This includes data to determine target off-block time (TOBT) and target time of arrival (TTA) to enable the user driven prioritisation process (see solution PJ.07-W2-39) and to better manage anticipated disruptions. An efficient interface requires all nodes feeding into the network operations plan (NOP) to adhere to common data parameters. In addition, there is a need to ensure compatibility between airport and network systems, as well as improve the capability of those systems to exchange data.

This candidate solution aims to rationalise and improve the data sets exchanged between the airport and the network through the integration of AOPs into NOP to provide standardised services/applications. There is also a need for new collaborative operational procedures in disrupted conditions, supported by tools, and capable systems to better manage disruptions, and speed up of the recovery to normal operations.





SJU ref: PJ.04-W2-29.1,
formerly PJ.04-02-W1

A MORE PROACTIVE APPROACH TO AIRCRAFT TURNAROUND

Airside/landside performance management

STAKEHOLDERS



Airside and landside processes in an airport have traditionally been managed in isolation, but in reality there is significant degree of coupling between the two with the performance of one process having the potential to impact the other. For example, landside events such as passengers not being at the gate on time can have ramifications on utilisation of parking stands. This candidate solution aims to enhance information sharing and collaborative decision making between the airside and the landside processes in an airport by means of a dashboard containing key performance indicators, decision support tools and enhanced predictions.

The candidate solution will also focus on the turnaround process. Through detailed monitoring of the different processes relating to turnaround, it will provide an early warning indicator of process and infrastructure inefficiencies or failures resulting in possible delays.

BENEFITS

- Enhanced efficiency
- Improved predictability
- Improved punctuality
- Enhanced resilience

The dashboard will include landside process outputs affecting ATM performance, including performance of airport access transport, passenger and baggage flow, and share these in the airport operations plan (AOP). It will allow different stakeholders to share the same vision and collaborate in root cause analyses. Support for decision-making will be enhanced by 'what-if' functionality and machine learning, for example presenting 'what has happened' and 'what is predicted to happen' to enable proactive management of solutions.



SJU ref: PJ.04-W2-29.2,
formerly part of PJ.04-02-W1

PROACTIVE MANAGEMENT OF WEATHER DATA ADDS RESILIENCE

MET performance management

STAKEHOLDERS



most up to date demand information, taking into account the prevailing and forecast weather information.

BENEFITS

- Enhanced efficiency
- Improved predictability
- Enhanced resilience

Efficient airport operations rely on users having access up-to-date information. This situational awareness can be enhanced to provide proactive management of airport performance to monitor, manage, and learn from operations. This candidate solution aims at increasing the resilience to meteorological events through anticipated and proactive management of their impacts on the airport operations plan (AOP). Total airport demand-capacity balancing (A-DCB) is achieved through the pro-active assessment of the available total airport capacity and the

The main aim of enhanced MET performance management is to minimise airport disruption to take-off or landing caused by weather events. Decision support functionalities are used to proactively manage the impact of weather on the AOP, and propose pre-defined solution scenarios. Local and/or network-based business intelligence, machine learning and 'what-if' should support this whole decision process and will be evaluated to determine where those could increase overall benefits.

Since the candidate solution is about pro-active management of meteorological impacts, the accuracy of the meteorological forecast is critical, as this is the base for impact assessments, 'what-if' analyses, etc. The required support includes dynamic information about the uncertainty of the weather forecast, provided by probabilistic interpretation of weather forecasts.

SJU ref: PJ.04-W2-29.3,
formerly part of PJ.04-02-W1



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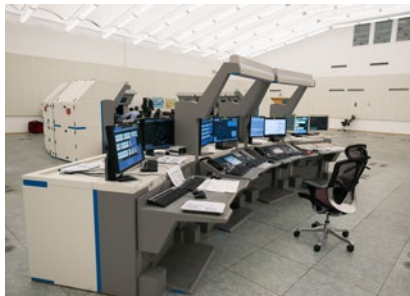
ENVIRONMENTAL IMPACT IS PART OF TOTAL AIRPORT PERFORMANCE

ENV performance management

BENEFITS

Improved environmental efficiency

European airports are committed to net zero carbon emissions by 2050, raising sustainable operations up the agenda. Environmental impact covers many areas including noise, air quality, biodiversity and water management and further research is required in the definition of specific and measurable environmental performance indicators which can be considered as appropriate for use in the airport operations decision-making process.



This candidate solution aims to integrate environmental considerations into the overall airport operations management process and improve environmental efficiency by exploiting environmental parameters in support of strategic or tactical decision-making. It aims to integrate these parameters (performance and restrictions) into the airport

operations plan (AOP) in planning, monitoring, execution and post-operations phases. Local and/or network-based business intelligence, machine learning and 'what-if' scenarios may support this process and will be evaluated to determine where they can increase overall benefits. The candidate solution will also define suitable ways to display such information along with appropriate alerting mechanisms.

The candidate solution will identify events that could trigger pre-tactical and tactical decisions during the pre-tactical phase - assessing the risk of threshold overshoot (noise, emissions, etc.) - and during the tactical phase by adjusting the pre-tactical forecast to the actual situation.

Regulatory authorities and trade organisations such as Airports Council International have a role to play in promoting the incorporation of environmental performance criteria into the total airport management performance-based approach.

SJU ref: PJ.05-W2-35,
formerly PJ.05-03-W1



STAKEHOLDERS



REMOTE TOWER SERVICES FOR MULTIPLE AIRPORTS

Multiple remote tower and remote tower centre

BENEFITS

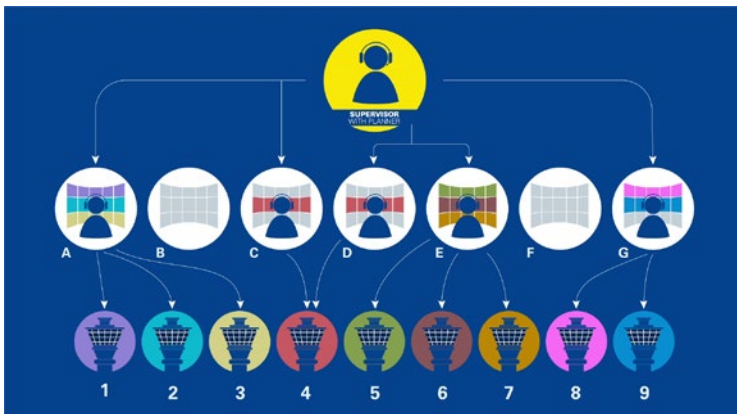
Enhanced safety
Increased cost efficiency
Improved human performance

Providing air traffic services to multiple airports from one location brings cost benefits in terms of shared resources, job satisfaction, human performance and training costs. A remote tower centre (RTC) equipped with a number of remote tower modules can provide services to one or more airports from each module.

To increase the number of airports and traffic volume that can be safely controlled from

a RTC, SESAR is examining the flexible and dynamic allocation of remote tower modules. The research looks at additional automation functionalities which can be integrated into the module, such as conformance monitoring and task prioritisation, in order to allow more airports to be controlled simultaneously from one module by one controller. Planning an efficient allocation becomes more complex with a RTC compared to a single module as any of the airports within the RTC can be grouped and ATCOs can be allocated to remote tower modules and airport in a dynamic way, depending on the traffic load at each airport and ATCO workload among other parameters.

This candidate solution considers support tools to assist the RTC supervisor in the task of allocating controllers and aerodromes in a remote tower centre. It enables a flexible and dynamic allocation of airports connected to different remote tower modules over time. In addition, the candidate solution addresses harmonised procedures across all the remote tower modules in the RTC to make it easier for controllers to hold endorsements for more than three airports.





TOWER CONTROLLERS EMBRACE MIXED REALITY

Virtual/augmented reality applications for tower

Virtual and augmented reality (V/AR) serves to ease staff tasks and enable more seamless operations. This candidate solution continues work already performed during SESAR 2020 wave 1 and aims to support tower controllers through the use of tracking labels, air gestures and attention guidance thanks to advanced human machine interface (HMI) interactions.

The V/AR blends real world images with computer-generated data (augmented reality) in real-time, so that visual information can be enhanced to improve identification and tracking of aircraft (or vehicles) on and around the airport. In low visibility, synthetic vision can show digital georeferenced data that supplement the missing real vision (virtual reality).

When using V/AR, auxiliary information is merged with the out of the window (OTW) view and presented as an overlay on top of the real-world visual information. In this way, controller attention is no longer forced to divide between

the primary visual field (OTW) and auxiliary tools (such as paper or electronic flight strips, surface movement radar, gap-filler camera streams and alert indications), consequently reducing 'head-down' time and increasing situational awareness.

The virtual reality application allows the controllers to interact with tracking labels by means of a set of air gestures and issue clearances for not-time-critical tasks (start-up, push-back).

Furthermore, the attention guidance function can be triggered by input from external sources, such as safety net or airport sensors, to display perceptual cues and direct the attention of air traffic controllers towards a specific event.

Computer-generated overlays can also be adaptively displayed by means of synthetic vision, for example in low visibility conditions.

STAKEHOLDERS



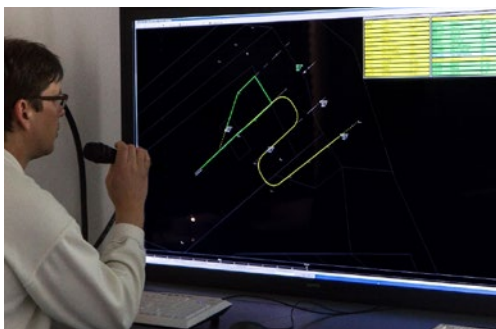
BENEFITS

- Enhanced safety
- Increased situational awareness
- Improved efficiency
- Improved resilience



TOWER CONTROLLERS REDUCE WORKLOAD WITH ENHANCED SPEECH RECOGNITION

Automatic speech recognition at the TWR CWP supported by AI and machine learning



Advanced technology including automatic speech recognition, artificial intelligence and machine learning offer potential enhancements to the controller working position (CWP). Building on work already performed during wave 1, SESAR 2020 is looking at control tower applications of this innovative technology using advanced human-machine interface (HMI) methods of interaction.

The automatic speech recognition (ASR) system transforms audio signals in a sequence of words

(speech-to-text) and transcribes this into air traffic control concepts (text-to-concept). This can be supported by a command hypothesis predictor to create an assistant-based speech recognition (ABSR) system. The ABSR figures out a set of possible command hypotheses derived from the contextual knowledge (surveillance data, flight plans, meteorological data, routing information etc.) to assist and speed up the speech recognition engine in choosing the right recognition hypotheses. This increases the command recognition rate and minimises command recognition error of standalone ASR.

The command hypothesis predictor that periodically receives contextual information can be supported by artificial intelligence and machine learning and used to predict possible future controller commands based on a machine-learned command prediction model on historic surveillance and speech data. The recognised commands are presented on an HMI for further acceptance or eventual correction by the controller.

STAKEHOLDERS



BENEFITS

- Increased efficiency
- Improved human performance



STAKEHOLDERS

- ANSP
- AO
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- NM

INNOVATIVE DATA INPUT REDUCES WORKLOAD IN THE TOWER

Interacting with tower CWP by means of touch screen (multi touch input)

BENEFITS

Increased efficiency

Improved human performance

The rise of multi-touch technology such as tablets or smart phones has heralded a new form of data input methods which are in some cases preferred to traditional input devices. This technology demonstrates faster input methods including 'one-touch' clearance or graphical routing via touch opportunities. The technology also allows for the exploitation of more complex tools such as map manipulation directly via touch inspired by mobile mapping apps and gestures recognition for tactical inputs that can enhance usability and controller productivity.

SESAR is examining the application of multi-touch for the controller working position (CWP) in the control tower. The innovative technology uses a touchscreen as a new means of interaction

with the traffic situation display (TSD), replacing or complementing the mouse, replacing the keyboard with a virtual keyboard, and introducing a new human machine interface (HMI) concept with touch events and gestures. As a result of multi-touch, controller data inputs into the system could become faster and more efficient without increasing the failure rate.

Further concept development includes investigating the use of gesture language for ATM, which may lead to further interaction efficiencies, for example through swiping, pinching and multi-finger gestures. The candidate solution improves CWP usability, reduces mental workload and increases task efficiency.



Advanced air traffic services

The future European ATM system will be characterised by advanced service provision, underpinned by the development of automation tools to support controllers in routine tasks. The feature reflects this move towards further automation with activities addressing enhanced arrivals and departures, separation management, enhanced air and ground safety nets and trajectory and performance-based free routing. The increased use of digital connectivity enables increased virtualisation of service provision, opening up more options for ATM service delivery.



ROTORCRAFT FLY SAFELY WITH SATELLITE-BASED NAVIGATION TECHNOLOGIES

Advanced rotorcraft operations in the TMA

Operating safely in constrained terminal or urban areas calls for accurate navigation by rotorcraft to ease access to environments such as large city airports, hospital helipads and remote locations in hostile areas. SESAR 2020 is evaluating navigation performance benefits of implementing dedicated rotorcraft procedures enabled by enhanced satellite-based technology. The candidate solution is expected to facilitate the mixed traffic management and contributing to the operational efficiency (rotorcraft flight efficiency), access and equity, capacity and safety.

The candidate solution makes use of multi-frequency, multi-constellation (MFMC GNSS) global navigation satellite system (GNSS) technology for more robust system coverage and improved signal availability. Higher integrity satellite navigation performance brings improved synchronization and resilience when carrying out procedures such as 3D approaches, point-in-space approaches and flying low-level instrument flight Rules (IFR) routes. It also helps to mitigate vulnerabilities arising from ionosphere disturbance and radio frequency interference affecting a single frequency.

New satellite receivers provide technical benefits including improved operational continuity, reduced false alerts and support more demanding performance-based navigation (PBN) specifications. Rotorcraft operations based on low required navigation performance (RNP) such as RNP0.1 will benefit from improved access inside the terminal area and airports close to urban areas. In fact, the enhanced IFR rotorcraft operations (based on RNP0.1) are expected to improve the current design criteria (e.g. buffer area, more flexible route design options, etc.), allowing for the creation of a network of rotorcraft routes/procedures that are strategically separated from the existing procedures for conventional fixed-wing aircraft.

The candidate solution supports more widespread use of instrument flight (IFR routes/procedures) operations in line with ICAO PBN goals and continued rationalization of conventional ground-based navigational aids.

SJU ref: PJ.01-W2-06

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BENEFITS

- Safer, more flexible operations
- Better integration between rotorcraft and fixed-wing aircraft
- Contributes to ICAO performance-based goals





STAKEHOLDERS



BALANCING ARRIVAL AND DEPARTURE CAPACITY AROUND AIRPORTS

Short-term DCB optimisation of TMA and extended TMA airspace with TMA management tools

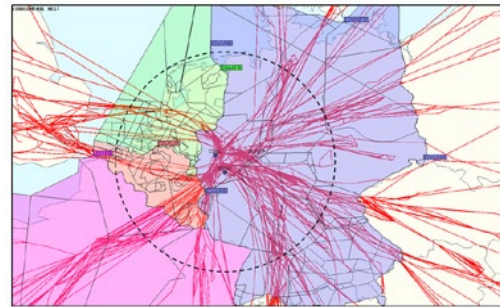
BENEFITS

- Increased capacity
- Improved flight efficiency
- Enhanced safety

Airports are important nodes in the ATM network. Providing more consistent delivery of arriving and departing traffic helps to optimise capacity at airports, especially where multiple airports are involved. This candidate solution will develop concepts for digital synchronisation of arrivals and departures in very high/high density/complexity environments.

The traffic in the terminal manoeuvring area (TMA) and nearby sectors is managed in near real-time, taking advantage of predicted demand information provided by local arrival and departure management systems to identify over-demand or additional capacity.

Sector load can be balanced by controlling sector entry times or waypoint times using instructions such as speed advisories, or ground delay. The candidate solution focuses on procedures and systems related to enhanced arrivals for nearby airports in the TMA. The aim is to manage and optimise arrival and departure flows in order to



improve the efficiency of inbound and outbound flows and to increase the capacity of the surrounding airspace.

The candidate solution enables departure flows to be managed in an integrated manner resulting in a more consistent and manageable delivery into the en-route phase of flight while ensuring an optimal usage of runway capacity.



STAKEHOLDERS



EFFICIENT MANAGEMENT OF ARRIVAL FLOWS

Automatic controlled time of arrival (CTA) for management of arrival in en-route and on the ground

BENEFITS

- Enhanced flight efficiency
- Improved environmental performance
- Supports ICAO performance-based goals

Air traffic is increasing in Europe, especially around major hub airports. Optimising airspace capacity in the terminal manoeuvring areas supports future growth along with improved flight efficiency and environmental performance. Planning arrival streams from an earlier stage enables delays to be absorbed in the en-route phases of flight, saving fuel and emissions compared with stack holding or long transitions in the terminal manoeuvring area. Research is

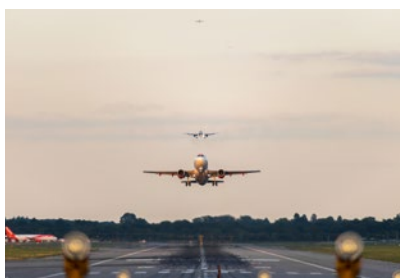
underway to further extend the arrival planning distance, and to incorporate more complex and high-density environments where the en-route sector serves more than one airport or terminal manoeuvring area.

This candidate solution develops concepts for digital synchronisation of arrivals and departures in high density/complexity environments.

Specifically, it investigates the concept of automated controlled time of arrival.

The proposed arrival constraints apply to the en-route phase and ground phase for “in-horizon” airports prior to start-up. SESAR is developing an extended arrival manager (E-AMAN) prototype that supports i4D/CTA, TTL/TTG advisories for the airport and provides sequencing of the traffic flow. The candidate solution will also develop and provide a “what-if” tool that will be necessary in order to automate the process through provision and insertion of an airborne trajectory modeller evaluating the expected aircraft behaviour with these constraints.

The candidate solution enables aircraft to fly more optimal trajectories and absorb delay on the ground instead or in the air, reducing fuel burn. It also improves queue management and results in more predictable landing times.





IMPROVING DESCENT OPERATIONS IN COMPLEX AIRSPACE

Dynamic TMA/E-TMA for advanced optimised descent operations

Adopting continuous descent approaches in place of conventional stepped approach paths, and optimising interacting arrival and departure flows, helps to reduce fuel consumption during arrival and departure phases of flight. This solution is based on six threads of research, focusing on:

B1: Descent phase support: arrival Management Streaming is used for optimisation of Systemised Airspace, controlling the entry time of arrivals into the systemised extended TMA (E-TMA) for deconfliction and delay absorption purposes. The streaming AMAN aims to identify and resolve complex interacting aircraft trajectories on single or merging flows through the E-TMA down to the runway, through the use of multiple AMAN target times.

B2: Seamless optimised descent Profiles through enhanced ground to air sharing: Efficiency of descents is increased through improved sharing of aircraft intentions and predictions with the ground, and the use of this information by the ground to better take into account the aircraft's optimal profile. Improved awareness by the flight crew of the ATC intentions should also be used to optimise the profile (low level-off or re-cruise, vertical speed adaptation, average vertical speed, energy management profile etc.) while complying with ATC separation and sequencing needs.

B3: Dynamic route structures for arrival synchronisation

This thread started investigating the dynamic deployment of route structures as a way to provide an agile response to variations in traffic demand throughout the day.

B4: Traffic optimisation within the TMA: Arrival and departure management information is used to manage the traffic in systemised airspace across primary and alternative (offload) routes to reduce route and stack over demand.

B5: Opportunities for reduction of airborne times induced by arrival management:

This thread of work is investigating the potential for reduction of additional airborne times induced by arrival management and to maximise environmental benefits through reduced airborne times.

B6: Vertical guidance mode to support optimised profile climbs:

Interacting arrival and departure flows will be optimised with a new vertical guidance mode supporting 'profile climbs' which will comply with the accuracy requirements of 3D departure tubes.

STAKEHOLDERS

**BENEFITS**

Improved environmental efficiency through optimised climb and descent profiles
Reduced low-level holding
Improved flight efficiency



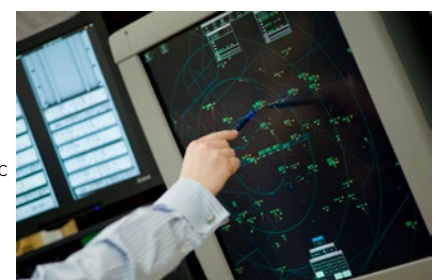
IMPROVING FLIGHT EFFICIENCY BY ADDRESSING AIRSPACE CONSTRAINTS

Collaborative control

Today, controllers are responsible for the management and safe separation of aircraft within their geographically defined sector. Any other controller wishing to control traffic in their sector must agree a coordination. Furthermore, controllers must coordinate traffic at sector boundaries using voice or electronic dialogue to maintain safe separation between aircraft at the point of transfer from one sector to the next. Using the SESAR solution of collaborative control, facilitated by advanced tools, controllers can issue instructions to aircraft beyond their sector, reducing the need for these coordination agreements. Additionally, fewer boundary constraints are required; only for separation or air traffic flow/complexity management purposes, therefore enabling more efficient flight profiles.

The concept, applicable to very high complexity airspace, includes the ability for one controller to

instruct (clear) an aircraft to enter a sector that is under the jurisdiction of another controller without a coordination being agreed explicitly first, either verbally or electronically. This is made possible through the introduction of the collaborative control toolset and procedures. Within a defined collaborative area, airspace is 'reserved' by the system for the controller who 'owns' the airspace based on the expected needs of flights in their sector, and the remaining 'free' airspace is available for the use of any other controllers. The candidate solution requires that the possible results of a collaborative action are shown to all relevant actors, therefore all controllers involved would be aware of the traffic situation and be able to separate their traffic without degradation in safety from current operations.



STAKEHOLDERS

**BENEFITS**

Enhanced capacity
Improved environmental performance
More efficient flight profiles



STAKEHOLDERS



BUILDING A SEAMLESS UPPER AIRSPACE TO DISTRIBUTE TRAFFIC MORE EFFECTIVELY

Flight centric air traffic control (ATC)

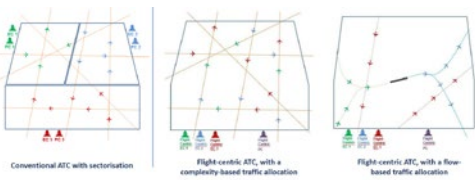
BENEFITS

Enhanced safety and capacity

Improved environmental performance

European airspace is divided into flight information regions, which are subdivided into sectors to provide safe separation services for aircraft travelling through the airspace. Changing this to a flight-centric structure without reference to geographical sectors opens up the opportunity to distribute the traffic more evenly, and to avoid lost productivity in under-loaded sectors.

SESAR researchers are validating the candidate solution in en-route environments where specific flights are assigned to controllers, who, unconstrained by geographical location or sector, are in charge of guiding each of these flights through a large airspace. With flight-centric ATC, the controller is no longer in charge of managing the entire traffic within a given sector. Instead, he/she is now responsible for a certain number of aircraft throughout their flight segment within a given airspace. This means that other controllers may also be working in the same airspace managing a certain number of different aircraft.



The candidate solution relies on the support of wide area communication over VHF in case the flight-centric area extends over approximately 200 NM, recognising that today the VHF radio coverage area is approximately 200 NM.

The research includes validating procedures for conflict detection and resolution; exploring different team set-ups and traffic allocation strategies; defining tools and procedures for demand and capacity balancing; and quantifying expected benefits. The flight-centric candidate solution requires new tools relating to traffic allocation. Advanced conflict detection and resolution tools are required which may have multiple functions. In the event of a conflict for example, it is important to determine which controller is responsible for its resolution. Furthermore, these tools can help to allocate conflicts to controllers.

The candidate solution is expected to increase of controller productivity owing to a better balance of the demand and increase flight efficiency by removing the sectors entry/exit conditions.



STAKEHOLDERS



TRAINING A FLEXIBLE, MORE AGILE WORK FORCE TO MANAGE FUTURE NEEDS

Increased flexibility of controller validations

BENEFITS

Increased flexibility

Improved cost efficiency

Air traffic controllers receive detailed and lengthy training to acquire a specific qualification to become, for example, an area controller or aerodrome controller. They also receive sector validations (unit endorsements), which permit them to control defined volumes of airspace. This restrictive sector validation makes it difficult to introduce new concepts, such as the flexible movement of sector boundaries or airspace changes in response to shifts in traffic flow. Increased flexibility in controller validations (IFAV) refers to the use of advanced tool/information support and harmonisation of ATC procedures that would enable controllers to hold more flexible validation regimes (unit endorsements) both within and across air navigation service providers.

As part of the work, researchers are investigating how validations could be based on a 'system' (a set of specific procedures and/or tools support) allowing controllers to provide ATC services based on a sector 'type' rather than expert knowledge of a geographically specified volume of airspace as in current operations. The system

must enable the controller to gain awareness of, and monitor, sector specific information, emergency situations, traffic levels/complexity and human performance. The result could be more efficient rostering and a reduction in time taken for controllers to train for and maintain validations. Such an approach would also support the roll out of additional SESAR candidate solutions, such as flight-centric ATC and collaborative control; in addition to simplifying controller schedules; harmonising training activities; improving staff usage, and easing staff transition to other units.





PROVIDING SERVICES REMOTELY WILL TRANSFORM THE WAY AIR TRAFFIC SERVICES ARE DELIVERED

Delegation of ATM services provision among ATSU's

The current rigid nature of Europe's airspace infrastructure makes it difficult to delegate airspace amongst air traffic service units based on traffic demand or organisational needs such as day/night operations. The operations and procedures to manage these two delegations have been developed over the years and work well in very low or zero traffic conditions but are severely limited in their capabilities.

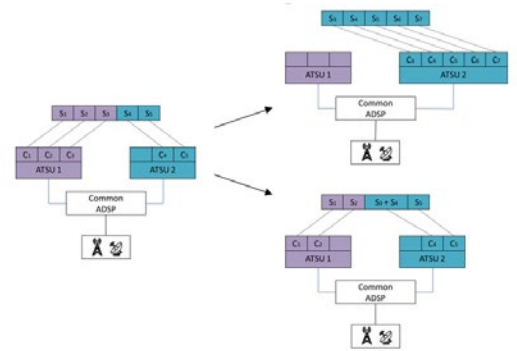
In fact, the present system lacks the means to transfer areas of responsibility between service units. Supported by appropriate technical Infrastructures to support the operational delegation and contingency use cases, some principles related to technical systems based on service-oriented architectures (SOA) must be considered for the virtual centre concept. This decouples the physical controller working position from the remote provision of ATM data and technical services such as flight data distribution and management.

SESAR is exploring the delegation of airspace in expected and planned situations - such as peak traffic load at fixed times - as well as unscheduled occurrences for example in cases of service

degradation or failure. The candidate solution is expected to lead to a cost optimisation for ANSPs, and to a capacity increase with the rationalisation of resources.

Delegation of airspace between service units may relate to an entire airspace or part of a larger airspace. The candidate solution encompasses the operational thread which aims at defining and validating the different types of delegation of airspace, and a technical thread which aims at specifying the impacts of the operational thread on the services defined in the virtual centre concept.

The aim is to enable greater flexibility when it comes to organising ATC operations and, in doing so, seamless and more cost-efficient service provision for airspace users. Other benefits are the flexible use of resources, which in turn leads to improved overall performance.



SJU ref: PJ.10-W2-93, formerly part of PJ.16-03 and PJ.15-09

STAKEHOLDERS



BENEFITS

Increased flexibility and operational efficiency

Improved cost efficiency

Increased resilience in terms of ATM service provision



INTELLIGENT TOOLS TO HELP CONTROLLERS PRIORITISE COMPLEX EVENTS

Attention guidance

Controllers in air traffic control (ATC) centres rely on the human machine interface

(HMI) of their controller working position (CWP) to manage the airspace. This is especially true for the CWP's situation data display (SDD) with regard to safely supervising current air traffic. Situational awareness and attention are two important skills that controllers need to keep at a high level when controlling aircraft at a radar screen.

For safety and efficiency reasons most CWPs issue a series of action indicators - such as information, warning, alert and finally alarm - if the assistance system detects a potentially dangerous traffic situation in the near or medium future. Due to the high complexity of some en-route environments, controllers must control significant amounts of traffic; SESAR research is examining a solution to address this workload and help manage the throughput of traffic in these busy and complex portions of airspace.

The candidate solution will make use of a "fade-out" algorithm implemented in the CWP that will place in the background (by means of colour) flights where controller intervention on spacing is not required, while drawing the controllers attention to the flights which may possibly interact with one another during their passage through the controlled airspace.

For the first time in such complex environments, the CWP will be able to take decisions about the priority of flights and those requiring the attention and support of the controllers. The candidate solution addresses controller workload and stress levels as awareness is enhanced and actions are executed close to the optimum times. Furthermore, controllers are 'ahead of the situation' and can handle high complexity traffic flows more easily.

SJU ref: PJ.10-W2-96 AG, formerly part of PJ.16-04

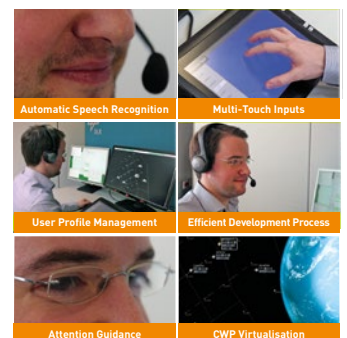
STAKEHOLDERS



BENEFITS

Increased productivity

Enhanced safety



SJU ref: PJ.10-W2-96 ASR,
formerly part of PJ.16-04



STAKEHOLDERS



SPEECH-TO-TEXT TOOLS EASE CONTROLLER WORKLOAD

Automatic speech recognition

BENEFITS

Increased capacity

Enhanced safety

Improved flight efficiency

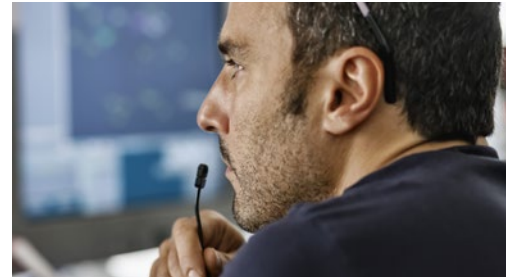
As in the previous candidate solution, controllers rely on their workstation to provide the support tools to manage air traffic and minimise workload in dense or complex airspace. Voice communications are central to controller activity yet risk being misheard or subject to congestion, prompting research into automatic speech recognition (ASR).

ASR takes audio signals and transforms them into text, for example for visualisation on the controller's display. This candidate solution covers three aspects of ASR with the aim of reducing workload and improving flight efficiency. The technology integrates artificial intelligence (AI) and machine learning algorithms to consider text predictions based on surveillance data; creating ATM commands based on existing ATC concepts; and a combination of both to provide further applications for the controller working position (CWP).

In detail, the ASR solution can analyse controller pilot communications and check commands against manual inputs. ASR can also highlight

the relevant radar label and reduce the need for manual inputs via mouse or keyboard. By predicting possible controller commands, it can check issued commands to ensure consistency, and can maintain a history of commands and readback for each aircraft. SESAR research is also examining how ASR may be used to enable faster and more predictable navigation in 3D visualisations of the airspace sectorisation when using dynamic airspace configuration (DAC).

Expanding on Wave 1 results, the candidate solution enhances safety and contributes to ASR standards development.



SJU ref: PJ.10-W2-96 UPMS,
formerly part of PJ.16-04



STAKEHOLDERS



ADDING A PERSONAL TOUCH TO CONTROLLER WORKING POSITION

User profile management system

BENEFITS

Increased capacity

Enhanced safety

Increased productivity

The controller working position (CWP) provides all the tools needed by a controller to manage the airspace and communicate with airspace users. An intuitive human machine interface (HMI) makes these operations easier and can help to minimise the workload and mental strain on controllers, especially when managing high traffic density or complex operations.

The manual process of configuring the HMI of their workstation by controllers when starting their shift or when there is a change in airspace configuration (e.g. re-sectorisation) is a time consuming process, usually at a time of high workload and stress. As a result, there are a disproportionate number of safety incidents reported during this configuration process. SESAR research is developing an automated process that enables an individual controller's HMI preferences to be stored for a variety of roles and reloaded when the controller identifies themselves to the system.



The candidate solution comprises an authentication system that allows controllers to identify themselves, a profile configuration system or software environment that enables controllers to define individual profiles, and automatic predefined profile coupling designed to minimise controller input.

The concept consists of two main packages: Development of an 'identification (authentication) system' and 'UPMS configuration system'. The research is ready to be moved to industrialisation in Wave 2.



ENHANCED DETECT AND AVOID SYSTEMS FOR UNMANNED VEHICLES

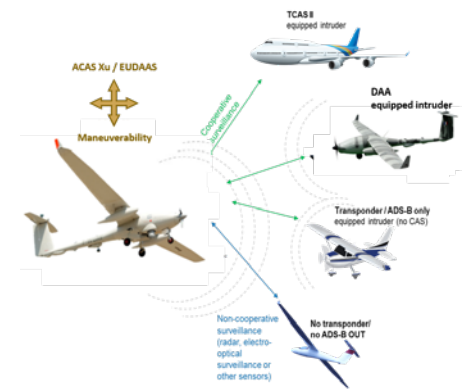
Collision avoidance for IFR RPAS

Most airborne collision avoidance systems (ACAS) are designed for commercial aircraft, however the growing number of remotely piloted aerial systems (RPAS) calls for ACAS capabilities between all airspace users. In addition, ACAS relies on Mode C/S interrogations for information when other sources such as ADS-B, electro-optical and infrared sensors are available.

SESAR features these additional surveillance sources as part of the ACAS Xu and the European detect and avoid system (EUDAAS) candidate solutions, both aimed at RPAS users. The research aims to operationally validate a detect and avoid (DAA) system for instrument flight rules (IFR) RPAS consisting of two functions: collision avoidance (CA) and remain well clear (RWC), in order to allow the remote pilot to contribute to safety by preventing collisions, should normal separation provision fail. The RWC function is designed to provide the remote pilot with enhanced situational awareness.

The candidate solution uses advanced mathematical models to optimise resolution advisories in horizontal vertical planes and considers additional factors affecting collision avoidance such as human factors and system latency.

The candidate solution can potentially help the integration of RPAS in the European airspace, and SESAR is also trying to harmonise this activity with similar programmes in other parts of the world including the US. Coordination between standards agencies EUROCAE and RTCA, which will contribute to the global design and standardisation of ACAS Xu and EUDAAS.



SJU ref: PJ.13-W2-111, formerly part of PJ.11-A2-W1

STAKEHOLDERS

ANSP	AO	AU	NM
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BENEFITS

- Enhanced safety
- Equitable access to airspace



QUICK AND EASY AIRSPACE ACCESS FOR UNMANNED VEHICLES TO/FROM DEDICATED AERODROMES

IFR RPAS accommodation in Airspace Class A to C

Remotely piloted unmanned aerial systems (RPAS) although already in state operations, are used under specific restrictions and segregations, for example flying predefined reserved corridors to their mission zones. The candidate solution responds to the need to operate RPAS transiting as non-segregated general air traffic (GAT) via controlled airspace to reach their mission areas.

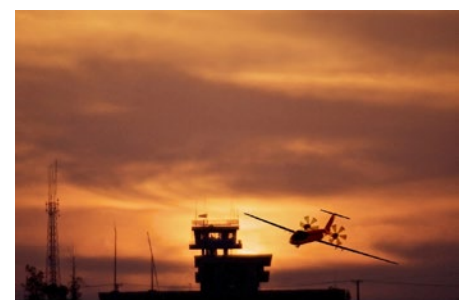
The candidate solution takes into account current military/state RPAS needs for flexible transit operations to their mission areas as non-segregated general air traffic (GAT) via controlled airspace. This represents the initial RPAS demand, which can be anticipated in the 2023-2025 timeframe.

SESAR partners are validating adapted RPAS accommodation procedures to alleviate existing restrictions. It will allow, in the short term, non-segregated RPAS flights in low to medium traffic levels and traffic complexity. The accommodation approach relies on existing ATM systems and capabilities that such RPAS have, which for some aspects may not be fully compliant with all existing manned aviation standards & rules.

Therefore, the solution focuses on adaptation, where needed, of operational procedures enabling:

- minimised planning and approval time needed for these transit IFR RPAS flights
- non-segregated RPAS transit during climb, en-route and descent phases of flight in controlled A-C class airspace, where RPAS fly with manned traffic and managed as general air traffic (GAT) by civil air traffic controllers.

The research is focussed on operational requirements and associated working methods for ATC to manage accommodated RPAS flights. The aim is to enable an initial accommodation of RPAS in non-segregated airspace with general air traffic (GAT) applying some limitations and with minimum possible impact on the existing ATM framework.



SJU ref: PJ.13-W2-115

STAKEHOLDERS

ANSP	AO	AU	NM
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BENEFITS

- Maintained safety and human performance levels
- Flexible and equitable access to airspace

SJU ref: PJ.13-W2-117,
formerly part of PJ.10-05-W1



STAKEHOLDERS

ANSP AO AU NM

SAFE AND PREDICTABLE ACCESS TO CONTROLLED AIRSPACE FOR UNMANNED VEHICLES

IFR RPAS integration in Airspace Class A to C

BENEFITS

- Enhanced safety
- Equitable access to airspace

Remotely piloted aerial systems (RPAS) have been used for many years by the military, but have been restricted to segregated airspace to protect their operations. With increasing demand for large civil RPAS, SESAR members are investigating how best to integrate these unmanned vehicles into non-segregated airspace alongside commercial manned traffic.



Managing RPAS traffic in the mixed environment of A to C airspaces is challenging for the air traffic control (ATC) due to several reasons. First, RPAS navigation performances may

significantly differ from conventional airliners. In addition, the latency in command and control links, as well as the possibility of link loss between the Remote Pilot ground control station

and the remoted piloted aircraft (RPA) in the air, may also require special mission patterns for contingency and emergency management.

In this context, this candidate solution aims at providing the procedural means and the technical capabilities to allow RPAS to comply with ATC instructions and operate safely in controlled airspace under instrumental flight rules (IFR), including contingency situations. This solution takes into consideration remote pilot and controller working methods, regulations, airworthiness standards, and technical challenges. It is expected to validate operational procedures and how new or adapted tools may allow ATC to handle IFR RPAS in a cooperative environment in full integration with manned aviation. It also complements research underway in the solution PJ.13-W2-111 which aims to enhance RPAS detect and avoid capabilities and harmonize standards.

SJU ref: PJ18-W2-53A,
formerly part of PJ.10-02b-W1



STAKEHOLDERS

ANSP AO AU NM

BIG DATA CONTRIBUTES TO MORE PRECISE TRAJECTORY PREDICTION

Increased automation in planning and tactical separation management

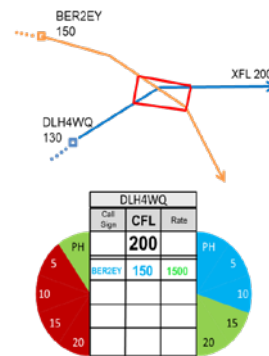
BENEFITS

- Increased capacity
- Reduced environmental impact
- Improved predictability

As traffic demand increases, so too does the need provide safe and efficient air traffic services. SESAR members are looking at automation tools to reduce controller workload, manage separation buffers and facilitate new controller team organisation for en-route and terminal manoeuvring areas phases of flight.

This candidate solution develops and validates the enhanced assistance provided by conflict detection and resolution for planning and tactical controllers and provides enhanced resolution support information based upon predicted conflict detection and associated monitoring features. It also provides additional trajectory prediction based on ADS-C and known constraints, and introduces machine learning and big data techniques to provide more accurate estimates.

Controllers are assisted in their separation tasks by technical functionalities which use advanced



data to improve the services provided. For example, ground trajectory prediction is enhanced when the ground system knows the complete flight profile through the full integration of ground trajectory

constraints with the air trajectory. This includes predicted climb and descent speeds downlinked from the aircraft using ADS-C and extended projected profile, as well as the integration of input data derived from meteorological services.

Uplink of altitude constraints allows the optimisation of climb and descents profiles that are compliant with ATC clearances while allowing the pilot to manage the flight economically with minimum environmental impact.



NEW PLANNING TOOLS DELIVER MORE PREDICTABLE FLIGHT TRAJECTORIES

Improved Performance of CD/R tools enabled by reduced trajectory prediction uncertainty

Controllers rely on a high number of tactical interventions and use multiple radar vectors, stepped climbs and descents in order to maintain separation between aircraft in high traffic situations. SESAR is looking at ways of delivering more accurate predictions of present and future aircraft positions through the use of aircraft-derived data in order to reduce the need for so many tactical interventions. By enhancing the accuracy of conflict detection, SESAR aims to improve the provision of separation services during en-route phases of flight and in the terminal manoeuvring area.

This candidate solution aims to provide the planning controller or tactical controller with conflict detection and resolution tools based on enhanced ground predicted trajectory obtained using improved aircraft data. This can include aircraft trajectory information downlinked via ADS-C, aircraft extended projected profile (EPP), electronic flight plan data (eFPL) and recent meteorological data. Additional trajectory information may also be made available using air/



ground data link exchanges using real recorded downlinked ADS-C data.

Research into the use of these advanced support tools is being carried out in the free route airspace environment in conjunction with extended air traffic control planning activities such as collaborative control described in solution PJ.10-W2-73 CC, and the multi-sector planning position and extended ATC planning role developed in wave 1.

SJU ref: PJ18-W2-53B, formerly part of PJ.10-02a2-W1

STAKEHOLDERS



BENEFITS

- Increased capacity
- Increased productivity
- Improved trajectory prediction



A FUNDAMENTAL SHIFT AWAY FROM TACTICAL VOICE CLEARANCES

Air/Ground Trajectory Synchronisation via lateral and vertical complex CPDLC clearances to support TBO

Current air traffic management is based on a filed flight plan and tactical interventions by ATC as the flight progresses. In current operations, multiple tactical instructions are issued with a limited use of CPDLC (reduced to simple clearances), and any no automated checks for air-ground trajectory consistency. The idea behind trajectory-based operations (TBO) is to enable the ATM system to modify, where appropriate, the flight's planned and actual trajectory before or during a flight based on accurate information that has been shared by all stakeholders. This will lead to efficiency gains for airspace users and the network as a whole.

This candidate solution makes use of enhanced operational procedures based on a more efficient use of controller pilot data link communications (CPDLC) with lateral and vertical data link clearances. The solution aims to leverage the usage of the current ATS Baseline 2 mandate and paves the way for future automation levels, as outlined in the European ATM Master Plan.

Thanks to automation, executive and planning controllers will be able to propose multi-element clearances with a longer look-ahead time. This may include proposals in advance by downstream sectors to modify or optimise portions of the trajectory while the flight is still in the current sector (the sector controlling the aircraft). Early and accurate knowledge of the FMS predicted trajectory will support the use of such advance clearances, enabling a move towards optimised pre-tactical traffic management.

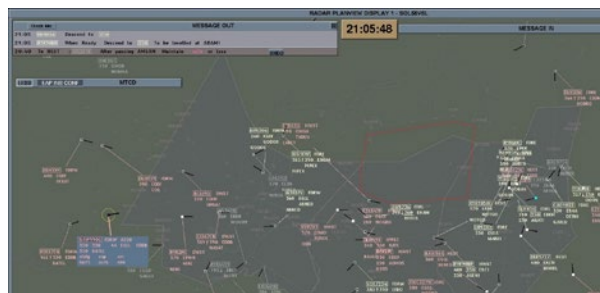
SJU ref: PJ18-W2-56, formerly part of PJ.18-02a-W1

STAKEHOLDERS



BENEFITS

- Increased capacity
- Improved controller and flight crew productivity
- Improved trajectory prediction
- Increased flight efficiency



SJU ref: PJ18-W2-57,
formerly part of PJ.18-
02a-W1



STAKEHOLDERS

ANSP AO AU NM

AUTOMATION TOOLS IMPROVE TRAJECTORY PREDICTION FOR ALL ACTORS

RBT revision supported by datalink and increased automation

BENEFITS

Increased capacity

Reduced controller and flight crew workload

Improved trajectory prediction

The SESAR concept is based upon the fundamental element of trajectory sharing. The goal is a trajectory-based ATM system where actors optimise their operations based on common trajectory information that takes into account user priorities and ATC constraints. SESAR research is helping to define the reference business trajectory (RBT) and data exchanges between these systems.

Research continues with the top-down approach taken in wave 1 on the definition of trajectory management processes, procedures and system support tools for all air and ground actors that will be necessary to support the trajectory-based operations (TBO) concept. Rather than address the complete range of tools, this candidate solution focuses specifically on the definition and validation of new, higher automation, exchanges. These apply to voice recognition, ground tools using big data analytics and machine learning,



machine reasoning and multi-criteria ranking of resolutions, and what-if air-ground trajectories.

Trajectory management improvements enabled by this solution are expected to increase capacity as a result of reducing the need to create a capacity buffer in case of trajectory uncertainty, and a reduction in controller workload due to fewer tactical and monitoring tasks. Thanks to better sharing of more accurate trajectories, extra controller capacity then becomes available to accommodate more traffic.

SJU ref: PJ18-W2-88,
formerly part of PJ.15-
08-W1



STAKEHOLDERS

ANSP AO AU NM

SHARING ONE CONSISTENT FLIGHT TRAJECTORY

Trajectory prediction service

BENEFITS

Increased cost efficiency

Reduced ATM fragmentation



Trajectory-based operations (TBO) is a cornerstone of the SESAR vision paving the way for more predictable air traffic management. Many areas of the programme and solutions in the pipeline rely on trajectory information which is captured in the SESAR architecture. In support of this transition, SESAR is researching a common service to provide a single point of reference for a specific trajectory during all phases of flight. The service covers the period from creation in long-term pre-flight planning through to the flight execution phase.

As a facilitator for TBO, the service provides a consistent flight trajectory and a common picture for all stakeholders. It is expected to reduce European ATM system fragmentation and contribute to cost-effective deployment of trajectory-based solutions.

The candidate solution aims to provide one generic facilitating service. It includes the following functions: A single reference trajectory; provision of trajectory information to support planning activity; access to this data by authorised stakeholders; provision of trajectories related to operational needs to the military; and access of flight trajectory information to other consumers subject to appropriate access rights. It aims to cover the pan-European area and deliver high service availability, response time and data accuracy. SESAR work includes technical concept definition and service feasibility analysis, and requires coordination with work on SESAR ground-ground interoperability activities.

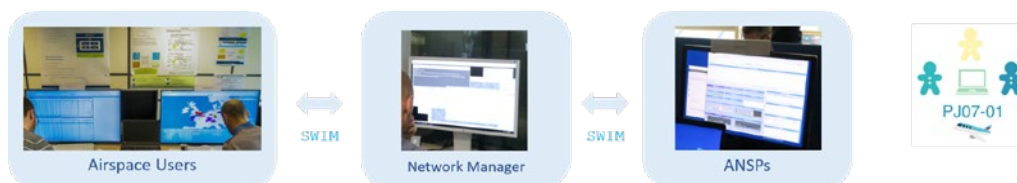
Optimised ATM network services

An optimised ATM network must be robust and resilient to a whole range of disruptions, including meteorological and unplanned events. An improved dynamic and collaborative mechanism will allow for a common, updated, consistent and accurate plan that provides reference information to all ATM actors involved in the planning and execution of flights. This feature includes activities in the areas of advanced airspace management, advanced dynamic capacity balancing (DCB) and optimised airspace user operations, as well as optimised ATM network management through a fully integrated network operations plan (NOP) and airport operations plans (AOPs), connected to the NOP via system-wide information management (SWIM).



PUTTING BUSINESS NEEDS IN THE DRIVING SEAT

Enhanced integration of AU trajectory definition and network management processes



Airspace users have varied business priorities, yet airspace management provides limited flexibility for users to incorporate specific aircraft or flight priorities into the requested trajectory. SESAR is researching ways to integrate processes within the flight operations centre (FOC), which help to manage and update the shared business trajectory with ATM network processes. This increases the FOC's role with regard to planning trajectory management, and investigates the impact of such integration on all stakeholders.

The aim is to fully integrate the FOC into the ATM network process through improved interaction tools which will deliver improved collaborative decision making throughout the trajectory lifecycle. This includes defining and validating an iterative trajectory planning process for each flight covering the creation of the trajectory, update, negotiation, and agreement. Once embedded inside the airspace

users' FOC, this will enable airspace management, and in particular the network management function, to accommodate airspace users' requests to fly a specific trajectory. The enhanced collaborative decision making between providers and users ensures a better adherence to the agreed trajectory during execution, hence better predictability.

The candidate solution also aims, through the flight delay criticality concept, to better integrate airspace user priorities in flow management decisions looking at short term implementation steps.

The candidate solution focuses on pre-tactical planning, tactical planning and execution phases of flight to support en-route traffic flow management. It also contributes to the development of flight and flow – information for a collaborative environment (FF-ICE) standards for trajectory exchange processes and FIXM information.

SJU ref: PJ.07-W2-38, formerly part of PJ.07-01-W1

STAKEHOLDERS

ANSP	AO	AU	NM
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BENEFITS

- Improved predictability
- Increased cost efficiency
- Reduced environmental impact

SJU ref: PJ.07-W2-39,
formerly part of PJ.07-02-W1



STAKEHOLDERS



GIVING AIRSPACE USERS A SAY IN ARRIVALS PLANNING

Collaborative framework managing delay constraints on arrivals)

BENEFITS

- Improved predictability
- Increased cost efficiency

When traffic is congested, airlines have little opportunity to propose alternative solutions to reduce the impact on their operations. SESAR 1 research initiated the user-driven prioritisation process (UDPP), which gives more flexibility to airspace users to reschedule their flights to keep their business-driven schedule priorities on track when facing capacity constraints and delays. For example, they can reorder flights in the congested airspace or airports.



This candidate solution extends airspace user capabilities, through the UDPP, to enable them to recommend a priority order request to the Network Manager, with other ATM stakeholders and appropriate airport authorities, for flights

affected by arrival constraints. It goes beyond the enhanced slot-swapping and departure flexibility introduced in SESAR 1 to provide a full set of prioritisation options and methods adapted to the different situations and types of airspace users.

SESAR is developing and validating the collaborative framework that will enable the integration and coordination of 4D constraints from various stakeholders including airports, air navigation service providers, airspace users and the Network Manager. This will ensure the continued stability and performance of the network and while giving airspace users the opportunity to prioritise their most important flights, hence reducing the impact of ATM planning constraints on the costs of their operations.

SJU ref: PJ.07-W2-40,
formerly part of PJ.07-03-W1



STAKEHOLDERS



SUPPORTING MILITARY USER NEEDS WITHIN THE NETWORK

Mission trajectories management with integrated DMAs Type 1 and Type 2

BENEFITS

- Enhanced en-route capacity
- Increased operational efficiency
- Reduced environmental impact
- Improved civil-military cooperation and coordination

Europe's armed forces operate more than 150,000 flights per year. To accommodate these flights, the airspace is often closed, sometimes at short notice, to civil traffic. Given the growth of air traffic demand and complexity, SESAR is developing operational and technical solutions that allow more flexible civil-military cooperation to maximise the use of airspace. Key to this cooperation is the integration of wing operations centre (WOC) and dynamic airspace configuration (DAC) functions and processes throughout the medium to short term ATM planning phase.

Building upon the previous SESAR achievements in the development of mission trajectory (MT) and advanced flexible use of airspace (A-FUA) concept elements, the candidate solution facilitates a step forward to a flexible and dynamic integration of military mission into the future European ATM environment.

The integration of dynamic mobile areas (DMA) type 1 and 2 into the definition and development of MT provides more options to military for tailoring the ATM planning to changing mission



requirements, including at short notice. Allocation of DMA type 1 and 2 within DAC processes supports airspace and traffic flow managers to dynamically adapting the configuration of airspace structures to the evolution of traffic demand.

Integration of MT data, shared via the iOAT FPL (Initial improved Operational Air Traffic Flight Plan), into the local/sub-regional traffic flow management enables a better balance between traffic demand and airspace capacity throughout civil-military collaborative decision-making (CDM) on time constraints.



CLOSING THE GAP BETWEEN CAPACITY PLANNING AND DELIVERY

Dynamic airspace configurations (DAC)

Managing airspace in a more dynamic way, for example by designing sectors based around predicted traffic flow, can increase capacity while reducing delays and emissions. SESAR is researching dynamic airspace configurations (DAC) which allows ANSPs to organise, plan, and manage airspace configurations with enough flexibility to respond to changes in traffic demand. The aim is to harmonise airspace management, flow management, and air traffic control during planning phases to deliver a seamless and dynamic process enabled by collaborative decision making (CDM) between civil and military stakeholders.

With DAC in place, it will be possible to manage dynamically all capacity elements and constraints in one single, seamless process and ensure the best possible balance of the different performance targets and operational requirements.

SESAR is refining the DAC operational concept and algorithm and developing an automated sector configuration proposal tool that takes account of 4D trajectory forecasts, fixed and flexible routing, and reserved or restricted airspace. The candidate solution builds upon extended ATC planning functionalities and an integrated network and ATC planning (INAP) working environment to enable local flow managers to work with extended ATC planners to assess and resolve hotspots. Full INAP capability will provide stakeholders with a common view for situation analysis and decision support to implement optimised solutions. SESAR aims to validate the integration of these different elements within a real operational environment.



SJU ref: PJ.09-W2-44,
formerly part of PJ.08-01-W1 and PJ.09-02-W1

STAKEHOLDERS



BENEFITS

- Enhanced capacity
- Increased cost efficiency
- Reduced environmental impact



BIG DATA BRINGS BETTER NETWORK PLANNING

Enhanced network traffic prediction and shared complexity representation

Planning traffic demand relies on knowing the intentions of airspace users and a range of factors that can impact flights. Demand prediction can be improved by establishing better route prediction i.e. assigning trajectories or trajectory elements that are reasonably likely to correspond to the airspace user response, taking into account the context and conditions. In this candidate solution, trajectories are calculated using AI techniques based on behaviour or decision-making patterns of airspace users facing similar conditions in the past.



The new model aims to improve the forecast of flight routes in the pre-tactical period, currently produced by the Network Manager. The model covers all flights, including incoming trans-oceanic traffic, and includes weather and progressively other features like flight delays and route changes.

This AI model for 3D route prediction "Predict AirCat" focuses mainly on scheduled flight plans and works as follows: For a given flight schedule, the AI model produces as output the forecasted initial flight plan. Each forecasted flight plan is accompanied by a confidence level or probability of occurrence and provides the most probable routes for the flight in question.

The first version of the AI model already shows significant improvements in route prediction. As a next step, once the model is further developed and validated, it will be integrated in the Network management tools to provide more accurate traffic forecast.

SJU ref: PJ.09-W2-45,
formerly part of PJ.09-01-W1

STAKEHOLDERS



BENEFITS

- Enhanced capacity
- Improved predictability
- Reduced environmental impact



STAKEHOLDERS



PUTTING COMMON INTERESTS IN THE DRIVING SEAT

Collaborative network performance management

BENEFITS

Enhanced capacity

Improved predictability

Reduced environmental impact



The ATM network is a complex system that involves the synchronisation of multiple operations and stakeholders. The Network Operations Plan (NOP) is a powerful tool that supports this process of demand-capacity balancing (DCB) by providing a common view of network performance indicators representative of the current and anticipated network situation. The NOP enables individual actors to design local solutions with minimal impact on network operations using upstream network performance indicators. To encourage the shift from local to regional management and improve DCB, SESAR is developing a network performance management dashboard tool (NPMD).

The candidate solution enables the pro-active management of network performance through the NPMD, increasing the network resilience through more efficient recovery plans to shorten the return to normal operations. The NPMD is designed to monitor the resilience of the network and anticipate, detect and monitor emerging disruptive operational situations across the system. The aim is to prevent an emerging degradation in one airport, or in one specific area in the en-route airspace, from having a cascading and potentially disastrous impacts on others.

The candidate solution enables the pro-active management of network performance through the NPMD, increasing the network resilience through more efficient recovery plans to shorten the return to normal operations.

Enabling aviation infrastructure

The enhancements described in the first three key features will be underpinned by an advanced, integrated and rationalised aviation infrastructure, providing the required technical capabilities in a resource-efficient manner. This feature will rely on enhanced integration and interfacing between aircraft and ground systems, including ATC and other stakeholder systems, such as flight operations and military mission management systems. Communications, navigation and surveillance (CNS) systems, SWIM, trajectory management, Common Support Services and the evolving role of the human will be considered in a coordinated way for application across the ATM system in a globally interoperable and harmonised manner.



SJU ref: PJ.14-W2-76,
formerly part of PJ.14-01-
01-W1



STAKEHOLDERS



TAKING ADVANTAGE OF CROSS-DOMAIN SYNERGIES TO CUT COST

Integrated CNS and spectrum

BENEFITS

Increased cost efficiency

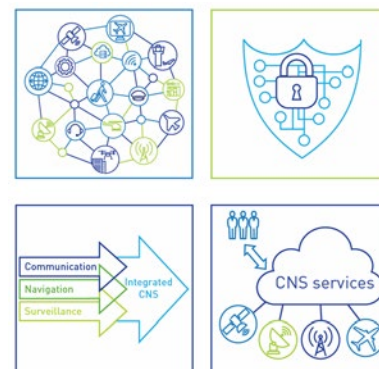
Increased civil-military coordination

Enhanced flexibility

One of the objectives of the Single European Sky is to reduce airspace user costs whilst improving safety and efficiency. The SESAR communication, navigation and surveillance (CNS) roadmap sets out to do this by integrating these three domains to take advantage of cross-domain synergies. Integrated CNS brings interdependencies between previously separate activities and introduces new requirements in terms of robustness, spectrum use, interoperability and service quality for all airspace users, including military.

SESAR is developing a performance-based approach to assess operational needs and to define a cross-domain robustness concept. This includes operating within the available spectrum and avoiding datalink saturation. It also includes a holistic approach to technology transfer opportunities, for example identifying what military can bring to civil, or general aviation to airport operations.

SESAR is addressing the evolution from the current fragmented infrastructure, which is built around separate areas of functionality, towards



a harmonised and cost-efficient infrastructure which features common performance criteria. The research pays special attention to cybersecurity and resilience considerations while still ensuring interoperability for civil-military CNS in current and future CNS infrastructure services and performance equivalence. In terms of performance expectations, a holistic analysis of the technical and safety requirements of the current and future CNS systems will highlight opportunities where the efficiency, safety, resilience and interoperability of the CNS infrastructure can be improved.

SJU ref: PJ.14-W2-60,
formerly part of PJ.14-02-01-W1



STAKEHOLDERS



SECURE DATALINK UNLOCKS FUTURE CAPACITY

FCI terrestrial datalink (LDACS)

BENEFITS

- Increased cost efficiency
- Enhanced safety
- Increased security
- Improved interoperability

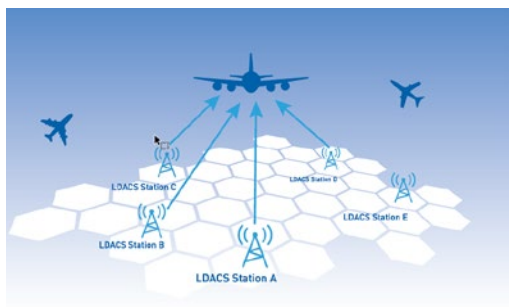
Reliable data is an essential building block of the European vision for the future communications infrastructure (FCI). Establishing secure communications between the ground and the air is vital to support the growth in traffic volume and complexity. The future operational concept of trajectory management in 4D – latitude, longitude, altitude and time – needs to be supported by a reliable, scalable, modular and efficient datalink technology. The adoption of 4D trajectory management concepts for separation

management will lead to more efficient flight paths, improved safety and fewer radio transmissions.

SESAR is looking at both avionics and ground infrastructure requirements for robust digital voice and data services. Among solutions under review,

SESAR is researching multilink technology in order to deliver higher data capacity, improved communications performance, lower transaction time and higher continuity. Specifically, it is developing and standardising the candidate future terrestrial datalink system L-band-digital aeronautical communication system (LDACS). This candidate solution will also address transversal topics and concepts, including the seamless transition from existing datalink technologies to LDACS and the provision of a ranging functionality in order to support navigation services as well.

The work is aligned with international standardisation activities at global level by agencies, such as ICAO, EUROCAE, RTCA and the Airlines Electronic Engineering Committee (AEEC), as well as ongoing research into future communications services capable of supporting a range of datalink applications.



SJU ref: PJ.14-W2-61



STAKEHOLDERS



PUBLIC WIRELESS NETWORKS COMPLEMENT IMPERFECT LEGACY RADIO

Hyper connected ATM

BENEFITS

- Increased cost efficiency
- Enhanced capacity
- Enhanced resilience
- Improved interoperability
- Enhanced flexibility

Aircraft safety-critical communications are currently supported using legacy systems such as VHF, HF and authorised L-band satellite systems operating within dedicated and protected spectrum bands. In parallel, non-safety commercial communication systems relying, for instance, on public cellular network like 4G (soon 5G) or commercial Ku/Ka band satellite communication services, are increasingly used on aircraft for passenger internet browsing or pilot-airline interactions. These systems benefit from technological advances in the public wireless telecommunication markets, evolving toward enhanced and cheaper services, unlike legacy aviation communications.

Current aircraft safety-critical communication systems support current needs, but face constraints, and future replacement systems risk being unsuitable or too late to support unforeseen shorter-term safety-related disruptive aircraft operations. SESAR is exploring the integration of public network services and commercial radio links to develop a hybrid open/protected 'hyper connected' communications



infrastructure for air/ground and air/air data to support future ATM and U-space operations.

The hyper connected ATM concept assumes that it will become acceptable and beneficial to use public non-safety commercial communication systems as a component of aircraft safety communications. This candidate solution aims to develop a concept of operations, identify use cases, capture high level requirements, and assess options of architecture to integrate commercial public network services into the future communications infrastructure (FCI).

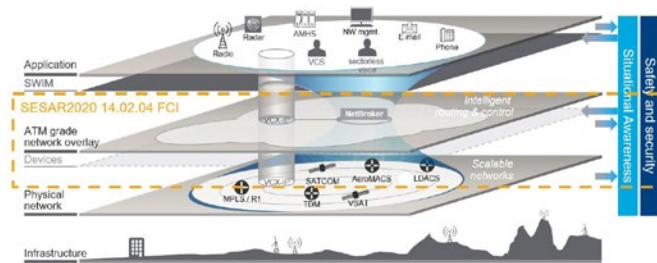


RESILIENT DATALINK INFRASTRUCTURE SUPPORTS CONTINUED GROWTH FCI Services

Europe's future satellite communications will need to support an increased number of aircraft, new types of manned and unmanned craft, as well as military air traffic. This demands higher datalink communication capacity and better performance than any kind of current communication system. SESAR is focused on developing an air-ground communication infrastructure capable of supporting future air traffic services in addition to flight operations centres (or military wing operations centres). A key part of resilient air-ground communications is the development of a future communications infrastructure (FCI) network infrastructure to support future service concepts and the migration towards internet protocol. The extension of a common, shared, integrated and resilient network infrastructure is necessary to enable SWIM applications and interfaces between all parties, including the military.

Timely access to airspace management data and information services is the first step towards enabling real-time sharing of trajectories in 4D. The SESAR research includes

completion of specifications for the FCI network infrastructure in order to support multilink capability and complete mobility between different datalink systems such as satellite communications (SatCom), LDACS, or AeroMACS. It also addresses civil-military interoperability requirements for ground/ground network interfaces, safety and security requirements. The candidate solution will improve safety and security, enhancing the efficiency and flexibility of the overall datalink system through the provision of resilient multilink and mobile communications capabilities to the aircraft.



SJU ref: PJ.14-W2-77,
formerly part of PJ.14-02-04-W1

STAKEHOLDERS



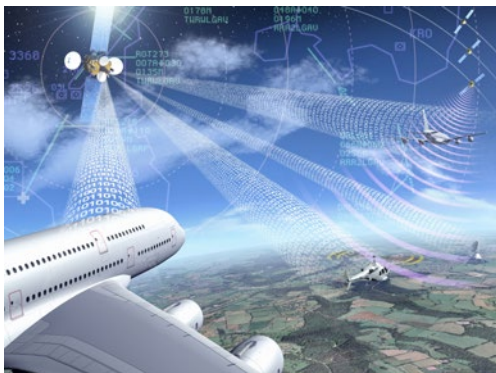
BENEFITS

- Increased cost efficiency
- Enhanced safety and security
- Improved interoperability



SATELLITE COMMUNICATIONS PROVIDE FUTURE EYE-IN-THE-SKY Future satellite communications datalink

Communication systems on board the most recent commercial satellite systems offer new capabilities to support airspace management communication needs. The technology is an essential part of the seamless, resilient and integrated future communication infrastructure (FCI) that will allow the real-time sharing of 4D trajectories and timely access to ATM data and information services. SESAR 1 successfully



tested a secure satellite-based air traffic services datalink (SatCom Class B), using the Iris Precursor, which takes advantage of IP-based broadband to provide secure and high-bandwidth cockpit communications to exchange flight information and trajectory data with the ground.

Complementary to this and as an element of the FCI, the SESAR JU programme is researching satellite datalink technology for the continental and remote/oceanic regions (long-term SatCom/Class A) including digital voice, to support the ATM concept in the 2025+ timeframe. In this respect, SESAR partners are working closely with European Space Agency (ESA) and the Iris Programme to ensure that communications services evolve to accommodate future communications requirements. The technology is among those identified by ICAO to support FCI services described in the preceding solution (PJ.14-W2-77 FCI services), and is expected to increase datalink availability and capacity, resulting in improved safety, security and resilience.

SJU ref: PJ.14-W2-107,
formerly part of PJ.14-02-02-W1

STAKEHOLDERS



BENEFITS

- Improved safety
- Increased capacity
- Enhanced availability



STAKEHOLDERS

ANSP AD AU NM

EVOLVING AIR/GROUND SERVICES TOWARDS OPEN STANDARDS-BASED INFORMATION SHARING

SWIM TI purple profile for air/ground safety-critical information sharing

BENEFITS

- Increased cost efficiency
- Enhanced safety
- Improve security



SWIM enables ATM information to be exchanged in a timely and accurate way. It operates in a network-centric environment by interconnecting multiple domain systems to provide accurate, accredited information to qualified parties. In the air/ground domain, SWIM allows the uplink and downlink distribution of safety-critical information through SWIM services over the aeronautical telecommunications network/ Internet protocol suite (ATN/IPS) in place of legacy point-to-point contracted services. SESAR aims to replace legacy services or seek to evolve them – such as those in place to support controller pilot datalink communications (CPDLC) and ADS-C – with an information distribution method over air-ground SWIM infrastructure. This enables, for instance, several ANSPs and airline operators

to subscribe to information over the ground-based SWIM network. Addressing the technical infrastructure of SWIM for air/ground services benefits many SESAR 2020 projects and provides a key building block for trajectory-based operations.

SESAR research is looking at safety critical requirements for air/ground information exchange and analysing service description documents (SDDs) for different ATM services. The work includes designing and validating the SWIM purple profile for safety-critical information sharing and concerns only the infrastructure layer. Key priorities include security, performance, safety, accessibility, maintainability and reliability, based on existing requirements for CPDLC and ADS-C services in use today. The candidate solution represents a technical enabler for the integration of the aircraft into the SWIM network enabling aircraft, flight crews and ground-based systems to benefit from SWIM concept and principles.



STAKEHOLDERS

ANSP AD AU NM

CIVIL-MILITARY COOPERATION AT GROUND LEVEL IMPROVES WITH SWIM

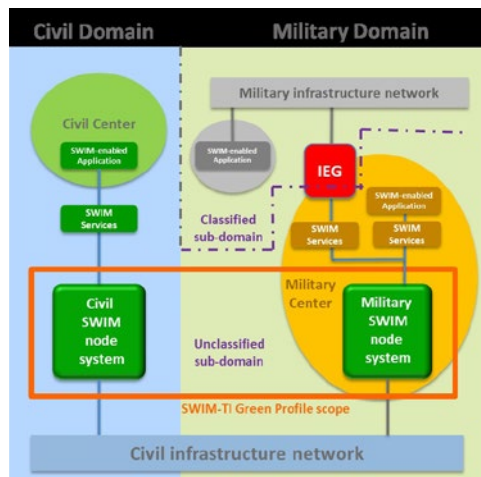
SWIM TI green profile for ground/ground civil-military information sharing

BENEFITS

- Improved cost efficiency
- Increased civil-military cooperation
- Improved interoperability

Information exchange between civil and military operators based on SWIM was first tested during SWIM TI yellow profile in SESAR 1. SESAR 2020 expands this bi-directional data flow to fully operational SWIM-based coordination and cooperation between civil and military

stakeholders and addresses cybersecurity. The SWIM technical infrastructure – or middleware – being developed in this scope exclusively centres on SWIM-based exchanges between military systems, such as ATC, air defence (AD) or wing operations centres (WOC) systems, and civil systems, such as ATC and Network Manager (NM) systems on the ground. Typical domains of interest include management of priority flights, military-specific requirements for air policing, sensitive data handling and resilience. The candidate solution is relevant to any operational environment where civil-military cooperation and coordination takes place. It can apply to existing SWIM services developed in SESAR 1, or future new services. To be relevant to all sectors, the military SWIM-enabled systems can be located in a military unclassified subdomain, or in a military classified sub-domain – such as AD. In the second case, the bidirectional data flow would go through an information exchange gateway (IEG) that connects both sub-domains in order to reach the military SWIM node located in the military unclassified sub-domain, which is connected to the civil infrastructure network.





SATELLITE-BASED PRECISION APPROACHES IN ALL REGIONS

GBAS - GAST-D extended scope

GBAS uses local augmented satellite signals to support precision approach operations for aircraft equipped with satellite navigation. The technology is used today in CAT I precision approaches down to 200 ft decision height. In comparison to instrument landing systems (ILS), GBAS allows more flexible procedure design with less infrastructure. Additionally, GBAS can provide resilience in low-visibility conditions, shorter routes, fuel-saving approaches, and precision approach on runways where ILS is not feasible.

SESAR 2020 aims to enhance the first generation CAT II/III GBAS to cope with adverse ionospheric conditions outside mid latitudes, thus enabling a globally deployable GAST D solution in more challenging environments including equatorial and Nordic regions. Technical problems are studied, such as multipath from obstacles and radio frequency interference at large and complex airports.

This candidate solution addresses cost-efficient infrastructure for operation and maintenance of GBAS in complex airport environments.

Among other, verifying VHF ground-air data broadcast (VDB) coverage can be challenging. In wave 1, SESAR 1 VDB measurement equipment was enhanced and a runway coverage simulation tool developed as means to verify that the VDB field coverage conforms with applicable ICAO Annex 10 Vol. I requirements. In wave 2, a horizontally polarised VDB measurement antenna to be located on the roof of a van is developed and used together with the VDB measurement equipment to technically verify ICAO Doc 8071 Vol. II ± 3 dB measurement uncertainty requirement. The work is expected to advance standardisation activities with the existing working groups at European and ICAO level.



SJU ref: PJ.14-W2-79a, formerly part of PJ.14-03-01-W1

STAKEHOLDERS



BENEFITS

- Improved resilience by limiting the capacity reduction in degraded situations
- Reduced installation and maintenance costs compared to ILS
- Maintained levels of safety
- Greater frequency efficiency
- Improved environmental impact due to shorter routes and noise abatement



REMOVING IONOSPHERE DISTURBANCE FROM SATELLITE-BASED NAVIGATION

Dual frequency/multi constellation DFMC GBAS - GAST F

Satellite based navigation systems such as ground-based augmentation systems (GBAS) support more flexible approach paths, shorter routes and require less infrastructure than conventional instrument landing systems. However, they can encounter interference in certain atmospheric conditions, and can become susceptible to jamming and spoofing. SESAR 2020 is examining the use of dual frequency multi-constellation (DFMC) to improve the robustness and performance of the navigation solution by making it less vulnerable to the presence of ionospheric disturbances.

DFMC GBAS considers any dual constellation combination. SESAR 2020 is studying DFMC GBAS with the aim of using GPS L1 and L5, and Galileo E1 and E5a constellations to support precision approach and landing operation in low visibility conditions up to CAT IIIb minima. The DFMC GBAS ground subsystem provides corrections (GPS/GALILEO) and integrity information as well as landing guidance to the aircraft, where is received and processed.

Having two frequencies improves the robustness of the system in environments of radio frequency interference affecting a single frequency. The availability of two constellations (GPS and Galileo in this case) stabilises the accuracy of the navigation solution as well as mitigates scintillation and the risk of having insufficient satellites with a single constellation.

The main goal is to develop a global solution capable of supporting landing operations in challenging conditions. In SESAR 2020 wave 1 the robustness versus extreme ionospheric conditions was studied, in Wave 2 ionospheric anomalies are being further studied thanks to a DFMC GBAS data collection system in Tenerife Norte Airport. Moreover, a concept paper was presented in 2018 and consolidated at European level, the objective is to advance on the standardisation activities with RTCA, ICAO/NSP architecture ad-hoc sessions and EUROCAE meetings.



SJU ref: PJ.14-W2-79b, formerly part of PJ.14-03-01-W1

STAKEHOLDERS



BENEFITS

- Improved cost efficiency
- Enhanced safety
- Reduced emissions

SJU ref: PJ.14-W2-81a,
formerly part of PJ.14-03-
04-W1



STAKEHOLDERS



ALTERNATIVE NAVIGATION MEANS IN CASE OF SATELLITE OUTAGE

A-PNT - multi-DME and RAIM algorithm

BENEFITS

Improved cost efficiency

Enhanced safety

Improved flight efficiency

Versatile and efficient PBN procedures rely on the availability of GNSS constellations, including Galileo. In the event of unexpected outage or degradation of satellite signals, aircraft require an alternative means of navigation. SESAR is researching alternative position, navigation and timing (A-PNT) using multiple distance measuring equipment (multi-DME) coupled with range autonomous integrity monitoring (RAIM) as a fallback in case of GNSS unavailability.

The candidate solution involves a standalone aircraft upgrade that supports required navigation performance (RNP)-based operations in the terminal manoeuvring area (TMA). It operates with standard instrument arrival (STARs) and standard instrument departure (SIDs) procedures designed with RNP constraints. SESAR 2020 is exploring the capability to fit multi-DME positioning in the existing flight management system (FMS) with RAIM algorithm to fully comply with RNP1 requirements (or even more stringent ones, still



under research) without any operational impact from the perspective of the flight crew or ATC, and using the existing DME ground infrastructure. This enables the aircraft to take advantage of redundancy provided by multiple DME in the TMA to prevent from the use in the positioning algorithm of possible erroneous DME measurements due to undetected anomalies.

The candidate solution aims to use DME localisation to provide 10-5 navigation integrity expected for RNP navigation in case of GNSS loss, which cannot currently be achieved by simply using legacy DME/DME. The capability also ensures full transparency for the flight crew and ATC.

SJU ref: PJ.14-W2-81b,
formerly part of PJ.14-03-
04-W1



STAKEHOLDERS



SPECTRUM-EFFICIENT NAVIGATION DURING PROLONGED SATELLITE OUTAGE

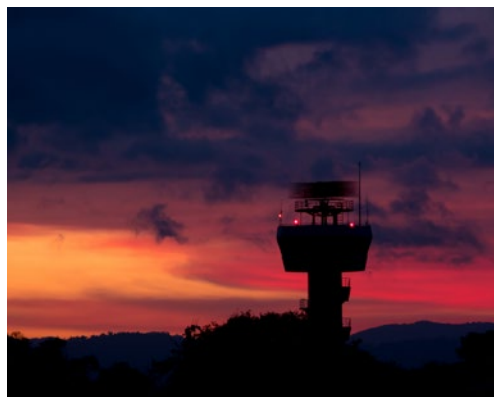
A-PNT - enhanced DME

BENEFITS

Improved cost efficiency

Enhanced safety

Aircraft navigate primarily using satellite-based signals, supported by ground-based infrastructure where needed. A prolonged outage of GNSS constellations, such as Galileo, has the potential to limit the ability of aircraft to take advantage of precise PBN procedures, impacting flight efficiency and airspace capacity.



SESAR is developing alternative position, navigation and timing (A-PNT) as a technical enabler to support PBN/RNP operations in case of extended GNSS degradation or outage. The candidate solution comprises enhanced distance measuring equipment (eDME) with capability to support more stringent A-PNT requirements. The technology is based on a coupling of the on-board interrogator and ground-based transponder equipment to provide a smooth and seamless implementation path and improved frequency band usage. The eDME equipment is expected to support more stringent RNP and improve spectrum efficiency, for example reducing L-band congestion. It anticipates minimum change to the on-board and ground hardware.

The research aims to introduce, in addition to the actual range capability (interrogation-reply), a pseudo-ranging (one way ranging), and to ensure that the additional capability is fully backward compatible in order to support seamless implementation.



L-BAND BACKUP IN CASE OF SATELLITE SIGNAL OUTAGE

A-PNT - LDACS analysis

Satellite signals from GNSS constellations, like Galileo, enable aircraft to follow precise flight paths and take advantage of PBN navigation procedures. Extended periods of signal interruption, for example as a result of signal degradation or satellite outage, can impact flight efficiency. SESAR is researching ways to maintain navigation performance during long-term signal disruption through the use of L-band digital aeronautical communications system (LDACS).

The candidate solution further studies LDACS as a complementary system for current navigation infrastructure, taking advantage of its development as a primary communication system. LDACS is one of most suitable candidates as it can be easily deployed with distance measuring equipment (DME) and is a driver for navigation infrastructure rationalisation, capable of meeting RNP0.3 requirements.

This candidate solution further examines ways to integrate inertial and terrestrial ranging sources



using sensor fusion technology. It proposes a new approach to GNSS inertial integration based on system-level modularity. This is achieved by computing the aircraft position as the weighted sum of position estimates coming from different systems. Modular Integrity enables a range of sensors and systems to be incorporated seamlessly into the aircraft navigation solution and can support a hybrid mix of navigation technologies and wide geographic coverage. This availability of multiple geographic measurements is crucial to integrity which is based on redundancy.

The maturity of the LDACS system for both ground and airborne applications will determine maturity of this solution.

Improved flight efficiency
SJU ref: PJ.14-W2-81c,
formerly PJ.14-03-04 in W1

STAKEHOLDERS



BENEFITS

- Enhanced safety
- Improved flight efficiency
- Spectrum efficiency
- Improved resilience



ONBOARD NAVIGATION REPLACES MISSING SATELLITE SIGNALS

A-PNT - Terrain aided and vision-based navigation



GNSS constellations like Galileo provide aircraft with the level of position accuracy to fly flexible and efficient precise flight paths. When satellite signals experience disruption or outage, aircraft navigate using alternative position, navigation and timing (A-PNT).

SESAR is examining selected alternatives to satellite-based navigation to support long-term outage or signals interruptions. This candidate solution aims to identify technological enablers for the A-PNT based on additional capabilities onboard aircraft or rotorcraft to provide increased

position accuracy in GNSS denied or degraded environment.

The candidate solution is developing and verifying a terrain-aided en route navigation solution for rotorcraft based on the terrain map, radar altimeter, barometer and inertial sensors. The candidate solution will allow operations such as emergency medical services and/or search and rescue at low level IFR in degraded environments, for example in low visibility conditions due to fog in mountains areas, or when satellite signals are denied or degraded as a result of GNSS masking or multipath issues.

In addition, SESAR research aims to develop and verify a vision-based navigation solution applicable to aircraft, likely to be based on active radar sensors, to support the demanding requirements of approach flight phases in all weather conditions. This is also expected to benefit less equipped airports as it needs no additional ground infrastructure.

SJU ref: PJ.14-W2-81d,
formerly PJ.14-03-04-W1

STAKEHOLDERS



BENEFITS

- Enhanced safety
- Improved resilience

SJU ref: PJ.14-W2-110,
formerly part of PJ.18-04c-W1



STAKEHOLDERS



STAY AHEAD OF THE WEATHER WITH ACCURATE ONBOARD DATA

Aircraft as an AIM/MET sensor and consumer

BENEFITS

- Enhanced safety
- Improved flight efficiency



Improved understanding and prediction of weather conditions contributes to enhanced flight safety and efficiency. In addition to information from on-board sensors, pilots receive updates in various formats via datalink including simple text messages, graphical products and satellite images. These inputs cover different timeframes, ranging from past observations to predictions for the next several hours. It falls to the pilot to organise and geo-reference this data, and temporarily build a mental picture as fast as possible. SESAR is examining novel and robust ways to support intelligent data pre-processing, smart filtering and integration, both on ground and on board the aircraft for the two-way exchange of meteorological data.

Moving to SWIM based technology will enable standardised exchange of information. One aspect of this solution is the definition and design of purple

profile SWIM services for meteorological data, which so far has no specification. The research is contributing to EUROCAE WG-76 and RTCA SC-206 MET datalink standardisation, and ICAO is also developing standards for turbulence and space weather which could be downlinked or uplinked via a SWIM purple profile service.

While up until now SESAR research primarily addressed on-board meteorological services, the focus now is on external inputs and intelligent pre-processing and integration of incoming data to foster accurate interpretation of the provided content.

SJU ref: PJ.14-W2-84a,
formerly PJ.14-04-03-W1



STAKEHOLDERS



NEW TECHNOLOGY FLOURISHES WITH PERFORMANCE-BASED STANDARDS

Multi sensor data fusion surveillance

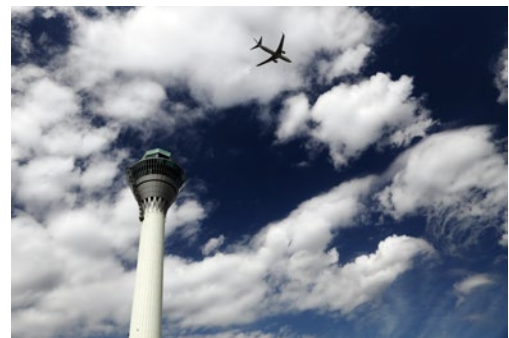
BENEFITS

- Improved cost efficiency
- Enhanced safety
- Improved interoperability

The growth in type and capability of cooperative and non-cooperative surveillance systems is helping to deliver increasingly cost-effective and versatile airspace and airport surveillance. This is supported by new standards, such as GEN-SUR-SPR developed by EUROCAE WG-102 and ESASSP V2 developed by EUROCONTROL surveillance standard task force (SSTF), which promote a top-down, performance-based approach to the provision of surveillance services.

SESAR aims to develop and harmonise the performance monitoring tools used to assess standards compliance. This represents an evolution from technology-driven standards to a safety-oriented approach that is technology agnostic. SESAR research aims to provide guidance and key performance indicators designed to assess the quality of surveillance data, and investigate new technics based on non-intrusive online performance assessments and interactions with the surveillance chain.

The objective of this candidate solution is to support the development of new surveillance



technology including non-cooperative systems like multi-static primary surveillance radar (MSPSR) and video trackers; as well as cooperative surveillance systems such as ADS-B, airport and wide area multilateration (MLAT/WAM) systems; and new optical sensors to support emerging operational needs like multiple remote tower surveillance. These new cooperative and non-cooperative surveillance technologies complement existing legacy sensor systems and will help to meet the new standards in a cost-effective way.



SJU ref: PJ.14-W2-84b,
formerly PJ.14-04-03-W1

COST-EFFECTIVE SENSORS AT SMALLER AIRPORTS

Multi remote surveillance module

Composite surveillance solutions have the potential to lower implementation costs and deliver appropriate levels of performance to meet the needs of regional airports or remote tower environments. This candidate solution aims to provide a surveillance service to increase situational awareness for the multi remote tower controller in a cost-effective way. It provides a basic surveillance service for a small to medium sized airport below the performance specified in ED-87D within a range of around 20 nautical

miles by augmenting the performance of existing surveillance equipment.

SESAR research aims to enhance the video camera plot extraction used as a non-cooperative source for the tailored multi-remote tower surveillance layer, consisting of video and infrared cameras, multilateration (MLAT) and multi-sensor data fusion (MSDF). The multi-remote surveillance module enables the event generation for multi-remote tower centre (MRTC) operation. A key element is the monitoring of stop bars between the taxiway system and the runway. The candidate solution also enables enhanced control of a pan tilt zoom (PTZ) camera.

STAKEHOLDERS



BENEFITS

Improved cost efficiency

Enhanced safety

Improved interoperability



The multi-remote surveillance solution defines a set of requirements for the technical solution enabling surveillance for multiple remote tower control. These requirements address the electro-optical sensor, the non-rotating Mode-S ranging component as well as the data fusion component. All three components are closely connected with one another to establish a logical surveillance layer.



SJU ref: PJ.14-W2-84c,
formerly part of PJ.14-04-03-W1

LOW-COST, SECURE SURVEILLANCE FOR SMALLER AIRPORTS

Secured surveillance systems (single and composite systems)

Advances in cooperative and non-cooperative surveillance systems open up opportunities to deliver a broader range of services and to operate within a wider range of environments. SESAR is looking at how to add new capabilities - such as security screening - to cooperative and non-cooperative surveillance systems including multi-sensor trackers, and ADS-B and wide area multilateration (WAM) systems.

implementation, and to deliver appropriate levels of performance; for example, to meet the needs of regional airports or remote tower environments. By combing sources of sensor data, at sensor level or on a display, surveillance data becomes more robust and secure. The security aspects will also help to remove barriers to entry for ADS-B.

SESAR research focuses on the security of single and composite cooperative surveillance systems and evolving threats from the RF-interface. The work includes analysis of security performance metrics in the absence of existing requirements. The candidate solution aims to identify dedicated security related key performance indicators for ADS-B, WAM, multilateration (MLAT) and the tracker function for single and composite surveillance. Composite surveillance in particular has the potential to lower the cost of

The candidate solution will analyse the metrics for the minimum detection and integrity performances achievable for the ADS-B, WAM and composite systems in terms of the functions of security continuity, integrity, time to alarm, and accuracy.

STAKEHOLDERS



BENEFITS

Improved cost efficiency

Enhanced safety



SJU ref: PJ.14-W2-84d,
formerly part of PJ.14-04-
03-W1



STAKEHOLDERS



INCREASED WAVEFORM CAPACITY WITH PHASE OVERLAY

Future ADS-B communications link

BENEFITS

Cost efficiency in terms of
technology cost per flight



Implementation of a wide range of surveillance technologies, including ADS-B, impacts data transmission. This candidate solution addresses the future ADS-B communications link, in particular phase overlay for Mode S and ADS-B datalink.

SESAR 2020 is using phase overlay techniques, which consists of overlaying phase-shift keying (PSK) onto the pulse position modulation (PPM) messages to carry separated information, avoiding the need to modify the structure of the current extended squitter message or assigned spectrum. The extended number of bits in a phase overlay message allows additional data

to be transmitted. This new extended data could be used to provide new types of information or complement current ADS-B PPM message. Also, Phase overlay technology opens the possibility for future applications. This data received in ADS-B messages, could improve aircraft situational awareness (e.g. providing weather information).

It could allow aircraft to better understand the environment, making appropriate decisions during the flight, increasing safety and reducing the risk of accidents. Additional data could also be used to secure ADS-B transmission avoiding threats as spoofing and eavesdropping. Finally, this higher rate of bit transmission could also be useful for V2V transmission in UAM environment. All these possibilities could be studied in future SESAR research projects.

Specifically, during Wave 2, PJ14-W2-84d aims to significantly improve the transmitted bit rate, increasing the data transmission from 112 to 448 bits (from 56 to 204 useful bits). The Candidate solution will validate the waveform and performances required for the phase overlay transmitter and receiver currently standardised on ED-102B / DO-260C and ED-73F / DO-181F and contribute to ongoing standardisation activities by RTCA SC-186 and SC-209, and EUROCAE WG-51, by providing feedback on the results of the candidate solution.

SJU ref: PJ.14-W2-84e,
formerly part of PJ.14-04-
01-W1



STAKEHOLDERS



UPDATED SURVEILLANCE MONITORING TOOLS LOWER COSTS

Surveillance performance monitoring tool for cooperative and non-cooperative sensors

BENEFITS

Improved cost efficiency
Increased interoperability

Surveillance plays a crucial role in ensuring airspace safety, security, capacity and efficiency. To ensure the detection of possible degradation trends early in the process, surveillance sensors are monitored on a regular basis to verify sensor performance figures. As surveillance sensor technologies and corresponding standards evolve, performance monitoring tools need to be aligned. Based on these new surveillance standards which are enabling a performance-based surveillance (PBS), this SESAR solution is working on detailed assessment methods to establish a baseline for performance assessment for the cooperative sensors: wide area multilateration (WAM), airport multilateration (MLAT) and ADS-B.

This candidate solution aims to harmonise the tools used for surveillance performance monitoring (SPM) and to align them with existing and developing surveillance standards (e.g. EUROCAE ED129- ADS-B, ED142- WAM, ED117- MLAT). The research builds on the detailed assessment methods and tools already developed in SESAR 2020 (wave 1) and adapts

the specifications to take into account emerging performance-based surveillance standards.

The candidate solution will contribute to cost efficiency through harmonised SPM tools amongst the larger user community, resulting in economies of scale. The near real-time performance monitoring also helps to reduce cost and raise efficiency due to early detection of performance degradations and the activation of appropriate procedures.





PERFORMANCE MONITORING OF THE SURVEILLANCE CHAIN

Surveillance performance monitoring – end-to-end

STAKEHOLDERS



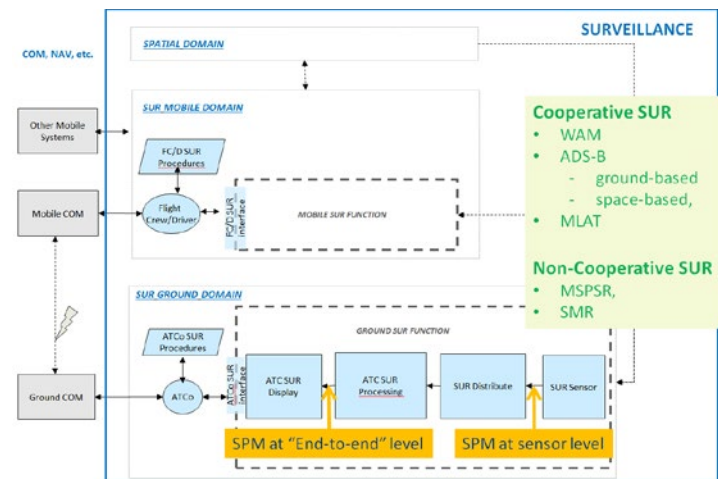
Many new surveillance systems such as wide area multilateration (WAM), multi-static primary surveillance radar (MSPSR), multilateration (MLAT), and space-based ADS-B provide lower cost alternatives to legacy cooperative and non-cooperative surveillance sensors. However, classical test methods and tools are not suitable for these new surveillance technologies. SESAR 2020 is developing new surveillance safety and performance requirements in line with performance-based surveillance (PBS) approach that can be applied regardless of the technology being monitored.

Employing the PBS approach, this candidate solution aims to enable improved performance monitoring of surveillance systems by developing specifications for tools used for surveillance performance monitoring (SPM). These tools can be applied to the surveillance chain at "end-to-end" just before the controller working position. The research aims to harmonise the specifications for these tools to match existing or developing surveillance standards (e.g. EUROCAE ED-129, ED-142, ED-261) and specifications (e.g. EUROCONTROL specification for ATM surveillance system performance - ESASSP).

The candidate solution is expected to enhance safety, capacity and security through the early detection of degradation trends as a result of real-time monitoring, and contribute to cost efficiency through harmonisation of common tools amongst a larger user community. The findings of this research will provide input to standards and safety regulations for surveillance systems and surveillance evaluation tools in cooperation with EUROCAE.

BENEFITS

- Improved cost efficiency
- Increased interoperability



Bonus candidate solutions (wave 3)

Some preliminary work has started on the next wave of solutions coming into the pipeline. See below for an initial list.

ATFCM aspects of airspace delegation across ATSUs SJU reference: PJ.32-W3-01	Defines the ATFCM processes and procedures needed to support the airspace delegation in case of traffic capacity imbalance, contingency, etc.
Increased flexibility in ATCO validations supported by advanced automation and procedures SJU reference: PJ.33-W3-01a	Aims to facilitate a more flexible deployment to air traffic controllers to specific portions of airspace, sectors and working positions, when and where needed.
Generic controller validations SJU reference: PJ.33-W3-01b	Refers to the development of advanced tools that will help to remove the qualification constraints imposed on controllers for controlling a single volume of airspace. This approach would allow controllers to operate in any airspace classified as a particular type.
LDACS digital voice capability SJU reference: PJ.33-W3-02	L-band-digital aeronautical communication system (LDACS) digital voice. See page xx for more details about the LDACS solution.
Collaborative U-space-ATM interface SJU reference: PJ.34-W3-01	Defines the requirements for information exchange between U-space and ATM through SWIM.
Highly-automated collaborative U-space-ATM interface SJU reference: PJ.34-W3-02	Aims to facilitate seamless operations of drones and manned aviation in non-segregated airspace.



On the horizon

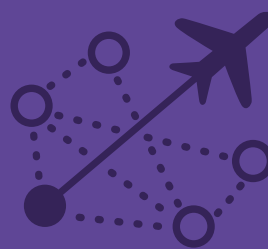
SESAR looks beyond current developments to investigate new ideas, concepts and technologies. By advancing promising research ideas and embedding them in a broader programme of work, the SESAR JU is helping to future-proof Europe's aviation industry and to maintain its global competitive edge. This section provides a full overview of the current projects in all three strands of research (exploratory, industrial and demonstrations), offering a flavour of what's in the innovation pipeline.



**High performing
airport operations**



**Advanced air traffic
services**



**Optimised network
operations**



**Enabling aviation
infrastructure**

SESAR research is categorised into three strands: exploratory research, industrial research and validation and very largescale demonstrations bringing together a wide range of aviation stakeholders, including air navigation service providers (ANSPs) regulators, airport operators, airspace users, the military, manufacturers (air and ground) staff organisations and the scientific community.



These strands have been designed as an innovation pipeline through which ideas are transformed into tangible solutions for industrialisation. The research takes place in over 50 test beds across Europe (simulation platforms, on-board commercial flights, dedicated airport testbeds and air traffic control centres), which validate concepts and candidate solutions (See map). The testing is not limited to a specific location, but can be used to test multiple environments irrespective of the location where the physical validation is held.

The following provides an overview of the current portfolio of research projects, highlighting the core focus of the programme.





AUTOMATION, ROBOTICS AND AUTONOMY

ARTIMATION – Transparent artificial intelligence and automation to air traffic management systems

ARTIMATION aims to investigate AI methods in predicting air transportation traffic and optimizing traffic flows based on explainable artificial intelligence (XAI) to address the challenge related to transparency of automated system in the ATM domain. ARTIMATION will provide a proof-of-concept of transparent AI models that includes visualisation, explanation and generalisation to ensure safe and reliable decision support.

Web: www.sesarju.eu/projects/artimation

AISA - AI situational awareness foundation for advancing automation

To implement advanced automation, AI and human need to be able to share situational awareness. Therefore, AISA project is exploring the effect of, and opportunities for, distributed human-machine situational awareness in en-route ATC operations. The project is developing an intelligent situationally-aware system by combining machine learning with reasoning engine.

Web: aisa-project.eu/

MAHALO - Modern ATM via human/ automation learning optimisation

To answer the question if automation should match human behaviour or be understandable to humans, MAHALO aims to develop an individually-tuned ML system to solve ATC conflicts and couple this to an enhanced en-route CD&R display. Insights will be used to define a framework to guide design of future AI systems.

Web: mahaloproject.eu

TAPAS -Towards an automated and explainable ATM system

TAPAS aims to explore highly automated AI-based scenarios through analysis and experimental activities applying explainable artificial intelligence (XAI) and visual analytics, in order to derive general principles of transparency which pave the way for the application of AI technologies in ATM environments, enabling higher levels of automation.

Web: <https://tapas-atm.eu/>



COMPLEXITY, DATA SCIENCE AND INFORMATION MANAGEMENT

AICHAIN – A platform for privacy-preserving federated machine learning using block chain to enable operational Improvements in ATM

AICHAIN proposes an innovative digital information management concept combining federated machine learning (FedML) and blockchain technologies. This enables the cyber-secured exploitation of large private data sets by a privacy-preserving federated learning architecture in which neither the training data nor the training model need to be exposed.

Web: www.aichain-h2020.eu/



ENVIRONMENT AND METEOROLOGY FOR ATM

CREATE - Innovative operations and climate and weather models to improve ATM resilience and reduce impacts

Air operations largely use weather information to make the air traffic flow safe, continuous and efficient. As climate changes are ongoing, available information on the weather on short and longer notice are increasing and technology is being improved. CREATE aims to achieve innovative procedures in ATM to reduce climate and environmental impact, while becoming more resilient to weather phenomena.

Web: <https://create-project.eu/>

DYNCAT - Dynamic configuration adjustment in the TMA

DYNCAT aims to enable more environmentally friendly and more predictable flight profiles in the TMA, namely on approach, by supporting the pilots in configuration management. The project will analyse the existing aircraft in operation and air traffic control procedures and propose improvements to on-board and ground procedures. The project will also identify the necessary technological and regulatory changes for improved airborne procedures and will assess the environmental potential of improved operations.

Web: www.sesarju.eu/projects/DYNCAT

FlyATM4E - Flying ATM for the benefit of environment and climate

FlyATM4E aims to expand approved climate-assessment methods and optimization of aircraft trajectories to identify promising mitigation options suitable to solve the task of reducing overall climate impact of aircraft operations. The project will assess the feasibility of a concept for environmental assessment of ATM operations working towards environmental optimisation of air traffic operations.

Web: flyatm4e.eu/

FMPMet - Meteorological uncertainty management for flow management positions

FMPMet aims to integrate meteorological forecast uncertainty information into the decision-making process for flow management position (FMP). FMPMet aims to provide the FMP with an intuitive and interpretable probabilistic assessment of the impact of convective weather on the operations, up to 8 hours in advance.

Web: fmp-met.com

See page 20 for more about this project!

SINOPTICA - Satellite-borne and in-situ observations to predict the initiation of convection for ATM

SINOPTICA aims to explore the potential of assimilating remote sensing, GNSS-derived datasets and in situ weather stations data into very high-resolution, very short-range numerical weather forecasts to provide improved prediction of extreme weather events to the benefit of ATM operations.

Web: <http://sinoptica-project.eu/>

ALARM - Multi-hazard monitoring and early warning system

ALARM aims to develop a prototype global multi-hazard monitoring and early warning system (EWS). A global multi-hazard monitoring means near-real time and continuous global Earth observations from satellite, with the objective to generate prompt alerts of natural hazards affecting ATM and to provide information for enhancing situational awareness and providing resilience in crisis.

Web: www.sesarju.eu/projects/ALARM



PERFORMANCE, ECONOMICS, LEGAL AND REGULATION

FARO - Safety and resilience guidelines for aviation

FARO aims to bring new insights about safety and resilience in ATM, with four objectives: to exploit existing safety knowledge, to quantify the impact of increasing automation on ATM safety, to analyse the impact of increasing automation on ATM resilience, and to provide design guidelines and identify future research needs.

Web: faro-h2020.eu/

BEACON - Behavioural economics for ATM concepts

BEACON aims to study the feasibility of extending user-driven prioritisation process (UDPP) to allow multi-prioritisation processes in the airspace and exchange of slots between airlines. It will build two models: a strategic model and a detailed tactical simulator. To properly capture the agents' behaviours, BEACON will make use of behavioural economics.

Web: www.sesarju.eu/projects/beacon

ITACA - Incentivising technology adoption for accelerating change in ATM

ITACA aims to accelerate the development, adoption and deployment of new technologies in ATM. ITACA will develop a new set of methodologies and tools enabling the rigorous and comprehensive assessment of policies and regulations aimed at amplifying the uptake of new technologies within ATM.

Web: <https://www.itaca-h2020.eu/>

SafeOPS - From prediction to decision support - strengthening safe and scalable ATM services through automated risk analytics based on operational data from aviation stakeholders

Maintaining safety and cost-efficiency of air transport operations while increasing the capacity will push the next generation of ATM systems towards digitalisation. In the mid-term, a digitalised system in the human operated ATM environment will be capable of delivering reliable predictive analytics based on automated information processing. SafeOPS aims to support these future services by investigating the use of big data analytics together with new risk assessment methodologies.

Web: www.sesarju.eu/projects/SafeOPS

SIMBAD - Combining simulation models and big data analytics for ATM performance analysis

SIMBAD aims to develop and evaluate a set of machine learning approaches aimed at providing state-of-the-art ATM microsimulation models with the level of reliability, tractability and interpretability required to effectively support performance evaluation at ECAC level. The project will demonstrate and evaluate the newly developed methods and tools through a set of case studies.

Web: www.sesarju.eu/projects/SIMBAD



INTERMODALITY

Modus - Modelling and assessing the role of air transport in an integrated, intermodal transport system

Modus analyses the performance of the overall transport system by considering the entire door-to-door journey holistically. The project identifies (future) drivers for passenger demand and supply and assesses the impact on airside and landside processes and capacities. Based on these analyses, potential solutions to meet high-level European transport objectives are proposed.

Web: modus-project.eu/

See page 19 for more about this project!

TRANSIT - Travel Information management for seamless intermodal transport

TRANSIT aims to develop a set of multimodal key performance indicators (KPIs), mobility data analysis methods and transport simulation tools, allowing the evaluation of the impact of innovative intermodal transport solutions on the quality, efficiency and resilience of the door-to-door passenger journey.

Web: www.transit-h2020.eu/

X-TEAM D2D - Extended ATM for door2door travel

X-TEAM D2D aims to define, develop and initially validate a concept of operations for the seamless integration of ATM and air transport into an overall intermodal network, including other available transportation means (surface, water), to enable the door-to-door connectivity, in up to 4 hours, between any location in Europe.

Web: xteamd2d.eu/

SYN+AIR - Synergies between transport modes and air transportation

SYN+AIR aims to generate common goals for transport service providers, which will justify data sharing while facilitating the user to execute a seamless D2D journey. SYN+AIR will generate customer door-to-door journeys and will analyse how those journeys can be facilitated through improved planning and operations activities powered by data sharing.

www.sesarju.eu/projects/synair



CNS FOR ATM

NewSense - Evaluation of 5G network and mmwave radar sensors to enhance surveillance of the airport surface

NewSense aims to improve safety and efficiency of operations primarily in secondary airports with innovative low-cost surface surveillance solutions, based on 5G cellular networks for the long term, and msafmWave radar for the medium term, allowing the implementation of affordable advanced-surface movement guidance and control systems (A-SMGCS).

Web: www.sesarju.eu/projects/NewSense

SINAPSE - Software defined networking architecture augmented with artificial intelligence to improve aeronautical communications performance, security and efficiency

SINAPSE aims to propose an intelligent and secured aeronautical datalink communications network architecture design, based on the software defined networking (SDN) architecture model augmented with artificial intelligence (AI) to predict and prevent safety services outages, to optimise available network resources and to implement cybersecurity functions protecting the network against digital attacks.

Web: 5.196.117.230/sinapse/



HIGH-PERFORMING AIRPORT OPERATIONS

AEON - Advanced Engine Off Navigation

AEON aims at defining a concept of operations focusing on engine-off taxiing techniques, and a set of dedicated tools to support the operators. The project defines how to determine, in real time, efficient and conflict-free routing plans for autonomous and non-autonomous aircraft taxiing from gates to the corresponding runways and the other way around.

Web: www.sesarju.eu/projects/AEON

ASPRID - Airport system protection from intruding drones

ASPRID aims to develop a service-oriented operational concept and system architecture to protect airport operations from unwanted drones. To do so, the project will analyse aircraft and airport (runway and ground) operations to pinpoint possible vulnerabilities. With this, the project aims to identify possible technologies, procedures and regulations that could help better safeguard against drone incursions and/or can help them recover from any disruptions as quickly and as efficiently as possible. In doing so, the project proposes a more integrated and coordinated approach to handling drone incursions.

Web: www.sesarju.eu/projects/ASPRID

IMHOTEP - Integrated multimodal airport operations for efficient passenger flow management

IMHOTEP aims to develop a concept of operations and a set of data analysis methods, predictive models and decision support tools that allow information sharing, common situational awareness and real-time collaborative decision-making between airports and ground transport stakeholders.

Web: www.imhotep-h2020.eu/



ADVANCED AIR TRAFFIC SERVICES

HAAWAII - Highly automated air traffic controller workstations with artificial intelligence integration

HAAWAII aims to research and develop a reliable, error resilient and adaptable solution to automatically transcribe voice commands issued by both air-traffic controllers and pilots, and to perform proof-of-concept trials in challenging environments. Also, the objectively estimated controllers' workload utilising digitised voice recordings of the complex London TMA will be assessed.

Web: www.hawaii.de



OPTIMISED ATM NETWORK SERVICES

CADENZA - Advanced capacity and demand management for European network performance optimisation

CADENZA aims to develop a detailed trajectory broker concept for the European network, incorporating advanced demand-capacity balancing mechanisms. The trajectory broker will balance capacity and demand through a coordinated capacity provision process and collaborative trajectory management (including a novel trajectory charging scheme). Significant improvements in cost-efficiency and delay are expected.

Web: <https://cadenza-project.eu/>

ECHO - European concept of operations for higher airspace operations

ECHO aims to deliver a comprehensive demand analysis and innovative and feasible concept of operations enabling near term and future higher airspace operations in a safe and orderly manner. The higher airspace including the operators forms a new, almost legacy free environment enabling an expeditions uptake of innovations or extrapolated SESAR solutions.

Web: <https://higherairspace.eu/>

ISOBAR - Artificial intelligence solutions to meteo-based DCB imbalances for network operations planning

ISOBAR aims at the provision of a service- and AI-based network operations plan, by integrating enhanced convective weather forecasts for predicting imbalances between capacity and demand and exploiting AI to select mitigation measures at local and network level in a collaborative ATFCM operations paradigm.

Web: isobar-project.eu/

START - A stable and resilient ATM by integrating robust airline operations into the network

START aims to develop, implement, and validate optimisation algorithms for robust airline operations that result in stable and resilient ATM performance even in disturbed scenarios. The main focus of the project is the optimisation of conventional traffic situations while considering disruptive weather events such as thunderstorms.

Web: start-atm.com



ENABLING AVIATION INFRASTRUCTURE

FACT - Future all aviation CNS technology

FACT aims to increase safety, security, efficiency, and robustness of future air traffic environment through development of integrated CNS functional architecture supporting the use of common performance based approach, addressing needs of large spectrum of airspace users across varied operational environments.

Web: www.sesarju.eu/projects/FACT



ATM OPERATIONS, ARCHITECTURE, PERFORMANCE AND VALIDATIONS

NOSTROMO - Next-generation open-source tools for ATM performance modelling and optimisation

The ATM system is composed of elements that interact with each other generating a number of properties characteristic of complex adaptive systems. NOSTROMO aims to develop new approaches to ATM performance modelling able to reconcile model transparency, computational tractability and ease of use with the necessary sophistication required for a realistic representation of the ATM system.

Web: www.sesarju.eu/projects/NOSTROMO

SlotMachine - A privacy-preserving marketplace for slot management

Until now, ATFM slots have only been subject to intra-airline swaps, used by airlines to prioritize expensive flights and thus minimise overall costs. Airlines want to keep the cost structure of their flights confidential, as they fear a competitive disadvantage when disclosed. This desire for confidentiality has hampered slot swapping between different airlines. SlotMachine aims to employ blockchain technology and secure multi-party computation to extend the existing UDPP solution with the possibility to keep private the participating airlines' confidential information, such as the cost structure of flights.

Web: www.sesarju.eu/projects/SlotMachine



RPAS

INVIRCAT - IFR RPAS control in airports and TMA

INVIRCAT aims to create a concept of operations for remotely piloted aircraft systems in the terminal manoeuvring area of airports, assessing it through simulations and draft a set of recommendations for rulemakers and standardisation bodies.

Web: www.invircat.eu/

SAFELAND - Safe landing through enhanced ground support

SAFELAND aims to support flight and landing of aircraft operated by a single pilot, in case of partial or total incapacitation of the pilot. SAFELAND will focus on the ground side, specifically on the role ATM could have in managing the transition from a single pilot operated flight to a status with reduced or absent contribution of the onboard pilot to landing.

Web: safeland-project.eu/

URClearED - A unified integrated remain well clear concept in airspace D-G class

URClearED aims to support current study activities on the RWC functionalities by defining and analysing operational scenarios, which allow to assess requirements and assumptions made in current standards and applicable documents, and then paving the way to future industrial level activities on such system.

Web: www.urcleared.eu



DRONES

BUBBLES - Defining the building basic blocks for a U-space separation management service

BUBBLES aims to formulate and validate the concept of a U-space advanced (U3) 'separation management service'. It will develop algorithms to compute the collision risk of UAS (Unmanned aircraft systems), allowing to define separation minima and methods, so that a safety level stated in terms of overall probability of collision can be defined and maintained.

Web: <https://bubbles-project.eu/>

DACUS - Demand and capacity optimisation in U-space

DACUS aims to develop a service-oriented demand and capacity balancing (DCB) process for drone traffic management. This overall objective responds to an operational and technical need in European drone operations for a tangible solution integrating the functionalities of the SESAR U-space services for drone traffic management (DTM) to produce timely, efficient and safe decisions.

Web: <https://dacus-research.eu/>

ICARUS - Integrated common altitude reference system for U-space

ICARUS aims to propose an innovative solution to the challenge of the common altitude reference inside very low-level (VLL) airspace with the definition of a new U-space service and its validation in a real operational environment.

Web: www.u-spaceicarus.eu/

See page 50 for more details about this project.

Metropolis 2 - A unified approach to airspace design and separation management for U-space

Metropolis 2 aims to provide the fundamentals for concrete solutions for U-space U3/U4 services that are needed to enable high density urban aerial operations, with a unified approach to the following U-space services: strategic deconfliction, tactical deconfliction, and dynamic capacity management.

Web: www.sesarju.eu/projects/Metropolis2

USEPE - U-space separation in Europe

USEPE aims to research drones' separation methods in high demanding environments, such as cities, and on the use of machine learning algorithms to automate the safe separation and deconfliction of drones, while maintaining airspace capacity in different environments. The research will take into account both the strategic and tactical flight phases.

Web: www.sesarju.eu/projects/USEPE

Industrial research and validation projects



NEW!

AART - Airport airside and runway throughput

(PJ.02 W2)

To improve the efficiency and resilience of arrival and departure operations at capacity constrained airports and access to secondary airports, the project addresses human, technical, procedural and performance aspects of the following proposed solutions: advanced geometric GNSS based procedures; separation minima for increased runway throughput; improved access to secondary; digital evolution of integrated surface management; and safety support tools for avoiding runway excursions.

Web: www.sesarju.eu/projects/aart



TAM - Total airport management

(PJ.04 W2)

European airports need become more operationally efficient. To this end, the project is developing concepts, tools and procedures to increase the predictability and resilience of airport operations, improving the punctuality of flights in a safe and environmentally sustainable manner. The aim is to improve airport/network integration for large and medium/regional airports, improve airport airside/landside integration, and reduce the impact of MET aspects on airport operations. The project is also investigating how environmental aspects can be better monitored and managed in day-to-day airport operations.

Web: www.sesarju.eu/projects/TAM2



DTT - Digital technology for tower
(PJ.05 W2)

The project aims to deliver two solutions: multiple remote tower and remote tower centre and human machine interaction (HMI) modes for airport tower. Those solutions are expected to positively contribute to safety and increase situation awareness and controllers' productivity. The variety of partners and validation activities will ensure that the variety of operational needs are reflected in technical solutions.

Web: www.sesarju.eu/projects/DTT

**TRANSVERSAL
PROJECT**

CI - Content integration,
performance management and
business case development
(PJ.19 - W2)

This project assesses the performance of the SESAR Solutions compared with the performance ambitions set out in the European ATM Master Plan. This is done in close collaboration and coordination with all SESAR 2020 projects through a continuous, rolling and iterative content integration process.

**TRANSVERSAL
PROJECT**

AMPLE - Master planning
(PJ.20 - W2)

The project brings together the SESAR community, ensuring the broad ATM representativeness required from air navigation service providers, airports, airborne and ground industry and Network Manager, in order to maintain the European ATM Master Plan, the roadmap on ATM modernisation.



EAD - Enhanced arrivals and
departures
(PJ.01 - W2)

The project is developing concepts, tools and procedures to optimise terminal manoeuvring areas (TMAs) in a safe, cost-efficient and environmentally sustainable manner. This will be achieved by taking advantage of the latest technological developments from both an airborne and a ground-system perspective and through the secure sharing of data. The needs of all airspace users are being addressed including rotorcraft. The aim is to exploit the environmental benefits achieved from continuous climb operations (CCO), continuous descent operations (CDO) and improved arrival sequencing. A focus is to minimise delays and improve resilience and predictability for high-density/complex TMAs.

Web: www.sesarju.eu/projects/EAD



PROSA - Separation management
and controller tools (PJ.10 W2)

The project is validating a series of separation management and controller tools aimed at boosting the performance of the air traffic system across all key areas. The project will focus on three solutions: flight-centric ATC and improved distribution of separation; delegation of airspace amongst air traffic service units (ATSU); HMI interaction modes for ATC centres.

Web: www.sesarju.eu/projects/PROSA2



ERICA - Enable RPAS insertion in controlled airspace

(PJ.13 W2)

The project is developing and validating the key operational and technological enablers that are necessary to ensure the integration of remotely-piloted aircraft systems (RPAS) into non-segregated airspace. These include a detect and avoid (DAA) system for IFR RPAS operating in airspace A to C for collision avoidance and a framework for allowing routine access and operations by RPAS.

Web: www.sesarju.eu/projects/ERICA



4D Skyways - Improving trajectory management for European air transport

(PJ.18 W2)

The project builds on research outcomes on trajectory management to enable a move towards trajectory-based operations (TBO). The focus is now on improving the ground trajectory prediction and separation management/ monitoring tools by using aircraft trajectory data, more precise weather data, improved algorithms and machine-learning techniques. The project is exploring new automation techniques that can support trajectory exchanges (big data, machine learning, voice recognition, etc) and define a common trajectory service as an alternative architecture for trajectory exchanges between ground ATM actors compared to the current fragmented approach.

Web: www.sesarju.eu/projects/4DSkyways



VC - Virtual centre

(PJ.32 W3)

Traditionally, ANSPs host a monolithic ATM system in each air traffic system unit (ATSU) with very few information services and infrastructure elements being shared between the different centres. In the virtual centre approach, the controller working positions are decoupled and may even be geographically separated from the ATM information services that they consume, and these ATM information services may be shared between different ATSUs or even between ANSPs. The project is further investigating the air traffic flow and capacity management (ATFCM) aspects of such airspace delegation among ATSUs.

www.sesarju.eu/projects/VC



FALCO - Flexible ATCO endorsement & LDACS complement (PJ.33 W3)

The project is investigating and validating technologies and procedures, enabling a more flexible and efficient re-organisation and endorsement of air traffic controllers (ATCOs), based on traffic complexity, sector classes and the level of skills, experience and training a controller has received on a specific class of working environment and supporting system. The project is also working on replacing analogue voice communication with a capability supported by l-band digital aeronautical communication system (LDACS) in order to improve air-ground connectivity.

www.sesarju.eu/projects/FALCO



I-CNSS - Integrated CNSS (PJ.14 W2)

The project is developing the future technologies coming from the communication, navigation and surveillance (CNS) domains in order to support and manage operational services, like the 4D trajectory management, in the future ATM system. Performance requirements for CNS systems are becoming increasingly complex and demanding and must be considered as part of an integrated and holistic system of systems and a unified concept of operations, where possible.

Web: www.sesarju.eu/projects/ICNSS



NEW!

OAUO - Optimised airspace users operations
(PJ.07 W2)

The project aims at defining and validating improved airspace user processes and tools in order to optimise ATM Network operations. The project is developing a collaborative framework managing delay constraints on arrivals; and mission trajectory management with integrated dynamic mobile Areas (DMA) Type 1 and Type 2. It is also looking at developing requirements and validating procedures and workflows for flight/wing operations centre to enable collaborative decision making between stakeholders throughout the flight trajectory. Other areas of focus include integrating airspace user (AU) priorities and preferences in airport and Network processes; making use of automation in collaborative decision making and coordination; better interoperability between AU and the NM operations.

Web: www.sesarju.eu/projects/OAUO2



DNMS - Digital network management services
(PJ.09 W2)

The project focuses on improving the network traffic prediction for all stakeholders involved in demand capacity balancing, dynamic airspace configurations, integrated network management and ATC planning and collaborative network performance management. This project is structured around three solutions: dynamic airspace configurations (DAC); enhanced network traffic prediction and shared complexity representation; and a prediction algorithm to anticipate the performance degradation in identified areas within the network.

Web: www.sesarju.eu/projects/DNMS



AURA - ATM U-space interface
(PJ.34 W3)

The project aims to identify the requirements for U-space information exchange with ATM through system-wide information management and will validate a set of selected U-space services, developing the service definition for the SWIM candidate services. It will also provide inputs for the current regulatory and standardisation initiatives regarding U-space with a high involvement of external stakeholders.

Web: www.sesarju.eu/projects/aura

Very large scale demonstrations



STAIRS - Airport surface management, airport safety nets and and ATSAW

(VLD02)

While safety has improved thanks to airport surface management systems, these systems do not fully resolve the risk of runway incursions and are not envisaged to be deployed at smaller airports. And although traffic collision avoidance systems (TCAS) has been in use since 1981, there is currently no aircraft system to prevent runway collisions. SESAR JU members and partners have developed a solution making use of ADS-B technology to provide on-board surface alerts (SURF-A & SURF-IA). This demonstration aims to assess the performance of this solution in real operational environments, in particular the absence of nuisance alerts. This will be the largest ground ADS-B IN trial worldwide, paving the way towards the deployment of SURF-A/IA or future ADS-B applications and standards.

Web: www.sesarju.eu/projects/STAIRS



ITARO - Integrated TMA, airport & runway operations

(PJ.37 W3)

The project plans to demonstrate on a larger scale several solutions in the airport environment, which research has shown can bring efficiencies, both operationally and environmentally. These include procedures to enable more efficient and integrated runway throughput and terminal operations; a collaborative framework for managing delay constraints on arrivals; and improved arrival and departure operations.

Web: www.sesarju.eu/projects/itaro



SORT - Improving runway throughput in one airport

(VLD03)

The expected rapid growth in air traffic will lead to an increasing number of capacity constrained airports. Therefore airports have to improve significantly the runway and airport throughput while maintaining or increasing runway safety levels. This demonstration will put to the test four solutions delivered by SESAR JU partners: PJ.02-01: Wake turbulence separation optimisation PJ.02-02: Enhanced arrival procedures PJ.02-03: minimum pair separations based on required surveillance performance PJ.02-08: Traffic optimisation on single and multiple runway airports. These will demonstrated several airports in Europe, including Heathrow, Vienna, Zurich and Stockholm Arlanda.



DREAMS- Demonstration of runway enhancements made with satellite navigation

(VLD01 W2)

This project aims to mitigate the climate impact of aviation through the development of meaningful and sustainable activities including efficient airport operations using GNSS technology and improved aircraft noise assessments.



ADSCENSIO ADS-C enables and supports improved ATM operations

(PJ.38 W3)

Building on the results of DIGITS, this project aims to demonstrate the efficiency and robustness of a technological infrastructure to support datalink communications between the aircraft and various ground consumers for real-time transmission of four-dimensional trajectory data. The aim is to support the industrial implementation of the use of automatic dependent surveillance-contract extended projected profile (ADS-C-EPP) data downlinked from aircraft – the target is for 45% of all flights in Europe to have the capacity to share trajectory.

See page 41 for more details about the project.

Web: www.sesarju.eu/projects/ADSCENSIO



ALBATROSS -The most energy efficient flying bird (VLD02)

ALBATROSS aims to support the transition towards greener and more sustainable aviation. Taking holistic approach, the project addresses all flight phases and demonstrate the complementary between airborne and ground solutions, such as alternative aircraft fuel, technologies for better air-ground connectivity, artificial intelligence and big data, and highly collaborative ATM procedures.

Web: www.sesarju.eu/projects/ALBATROSS



VOICE - Reduced separations and improved efficiency based on Vhf cOmmuniCations over LEO satEllites (VLD02)

The project is demonstrating the benefits of using satellite-based VHF systems for voice and datalink air traffic services in remote and oceanic airspace where currently there is no coverage, especially in reducing separation without compromising on safety. Project partners will perform demonstration activities in oceanic areas where currently there is no terrestrial coverage, will demonstrate the viability of space based infrastructure as backbone for current terrestrial airspace and will also perform cross-border operations to illustrate the feasibility of using these technologies across national borders.

Web: www.sesarju.eu/projects/voice

AMU-LED - Air mobility urban large experimental demonstrations

The project aims to develop a detailed concept of operations and define urban air missions followed by simulations and a large-scale real flight demonstration campaign to verify and validate the concepts. The project will allow UAM stakeholders to specify various use cases applicable to logistics and urban transport of passengers, design or integrate UAM environment, test the UAS ground and airborne platforms and finally, assess safety, security, sustainability and public acceptance.

Web: <https://amuledproject.eu/>

CORUS-XUAM – Concept of operations for European U-space service – extension for urban air mobility

CORUS-XUAM will demonstrate how U-space services and solutions could support integrated urban air mobility (UAM) flight operations, allowing eVTOLs/UAS and other airspace users (unmanned and manned) to operate safely, securely, sustainably and efficiently in a controlled and fully integrated airspace, without undue impact on operations currently managed by ATM. The project is proposed by the consortium that delivered the CORUS U-space ConOps in 2019, extended by the addition of UAM expertise.

Web: <https://corus-xuam.eu/>

GOF 2.0 - Integrated urban airspace very large-scale demonstration

The project will demonstrate operational validity of serving combined UAS, eVTOL and manned operations in a unified, dense urban airspace using current ATM and U-space services and systems. Both ATM and U-space communities depend extensively on the provision of timely, relevant, accurate and quality-assured digital information to collaborate and make informed decisions.

Web: www.sesarju.eu/projects/GOF2

SAFIR-MED – Safe and flexible integration in advanced U-space and flexible services focusing on medical air mobility

The project will combine five unmanned UAV platforms (passenger eVTOL, hydrogen fuel cell VTOL, AED medical drone, X8 medical transport) with manned aviation in real-life demonstrations validating technology and the maximum number of U-space services in real urban environments. The results are expected to help refine the current U-space architecture principles and create measurable indicators for the inclusion on UAM smart city transport roadmaps, supporting standardisation and safety.

Web: <https://www.safir-med.eu>

TINDAIR - Tactical instrumental deconfliction and in flight resolution

The project aims to demonstrate and refine the safety, performance, standardisation and regulatory requirements to enable UAM with specific focus on U-space U3 services identified in the U-space Blueprint and refined by CORUS, and, unlock new and enhanced applications and mission types in high density and high complexity areas.

Web: <https://tindair.eu/>

Uospace4UAM - U-space for UAM

The project will carry out a series of multi-national demonstrations, both with drones and UAM, covering different use cases, including mixed operations, to derive critical enablers for a wide set of UAM service applications that can be applied all over Europe.

Web: www.sesarju.eu/projects/Uospace4UAM

Conclusion

The SESAR JU will continue to build on the content of this catalogue, with the aim of moving more of the candidate solutions to the next level of maturity and ultimately deliver for market take up. In this respect, the next edition of this catalogue will detail further progress in the development, validation and delivery of solutions in line with the European ATM Master Plan and the objectives of SES and the European Commission's Sustainable and Smart Mobility Strategy.

The focus will be on the further integration of airports into the air traffic network; the implementation of advanced air traffic services such as satellite-based navigational aids; integrated arrival and departure management tools, and free route airspace; and optimising network services through increased dynamic data sharing between airlines and air traffic control.

Through this R&D work, SESAR JU members and partners will aim to bring benefits in key performance areas of safety, operational efficiency, security, capacity and the environment, fast-tracking solutions to meet individual stakeholder challenges or improvements to the overall network.



ANNEX 1

Overview of implementation per delivered solutions

Work is underway to industrialise and subsequently deploy many of the delivered solutions in the SESAR Solution Catalogue. This includes the development of operational systems, standardisation activities and development of procedures and systems (up to certification based on the availability of regulatory material). Out of the 99 solutions delivered so far, over 75 have been implemented, including 24 solutions as are part of Europe-wide synchronised deployment¹. Meanwhile, many of those remaining are part of procurement specifications for future implementation in locations across Europe.

Furthermore, SESAR Solutions are designed in full accordance with the ICAO standards and the Global Air Navigation Plan (GANP) and are therefore applicable to ATM environments. This has led to their take-up in other world regions.

The table gives an overview of the state of implementation in Europe² (completed local implementations or synchronised deployment), arranged according to solution number.

¹ COMMISSION IMPLEMENTING REGULATION (EU) 2021/116 of 1 February 2021 on the establishment of the Common Project One supporting the implementation of the European Air Traffic Management Master Plan provided for in Regulation (EC) No 550/2004 of the European Parliament and of the Council, amending Commission Implementing Regulation (EU) No 409/2013 and repealing Commission Implementing Regulation (EU) No 716/2014

The following airports are concerned: Adolfo Suarez Madrid-Barajas; Amsterdam Schiphol; Barcelona El Prat; Berlin Brandenburg Airport; Brussels National; Copenhagen Kastrup; Dublin; Düsseldorf International; Frankfurt International; Milan-Malpensa; Munich Franz Josef Strauss; Nice Cote d'Azur; Palma De Mallorca Son Sant Joan; Paris-CDG; Paris-Orly; Rome-Fiumicino; Stockholm-Arlanda; Vienna Schwechat (and Oslo Gardermoen, Zürich Kloten and Geneva airports into its scope insofar as ATM functionalities 1, 2, 4 and 5 are concerned).

² Sources used to compile this annex include:

- SESAR Deployment Programme
- Master Plan Level 3 Implementation Report (2021)
- Think Research (<https://think.aero/insights/resources/remote-and-digital-tower-operations/>)
- SESAR JU members and partners

Reference	Solution name	Local implementation	Synchronised deployment
#01	Runway status lights	Paris Charles de Gaulle	n/a
#02	Airport safety nets for controllers: conformance monitoring alerts and detection of conflicting ATC clearances	n/a	In progress
#04	Enhanced traffic situational awareness and airport safety nets for vehicle drivers	n/a	In progress
#05	Extended arrival management (AMAN) horizon	n/a	In progress
#06	Controlled time of arrival (CTA) in medium-density/medium-complexity environments	Austria	n/a
#08	Arrival management into multiple airports	Germany (Cologne Bonn and Dusseldorf)	n/a
#09	Enhanced terminal operations with RNP transition to ILS/GLS	Cyprus, Malta, Montenegro and Slovakia	n/a
#10	Optimised route network using advanced RNP	Italy	n/a
#11	Continuous descent operations (CDO) using point merge	Austria (Vienna), France (Paris Charles de Gaulle) and the UK	n/a
#12	Single remote tower operations for medium traffic volumes	London City, Saarbrücken	n/a
#13	Remotely-provided air traffic services for contingency situations at aerodromes	Budapest, Jersey	n/a
#17	Advanced short-term ATFCM measures-STAMs	n/a	In progress
#18	Calculated take-off time (CTOT) and target time of arrival (TTA)	n/a	In progress
#19	Automated support for traffic complexity detection and resolution	n/a	In progress
#20	Initial collaborative network operations plan (NOP)	n/a	In progress
#21	Airport operations plan (AOP) and its seamless integration with the network operations plan (NOP)	n/a	In progress
#22	Automated assistance to controllers for surface movement planning and routing	n/a	In progress
#27	Enhanced tactical conflict detection & resolution (CD&R) services and conformance monitoring tools for en-route	23 countries across Europe	n/a
#31	Variable profile military reserved areas and enhanced civil-military collaboration	n/a	In progress
#32	Free route through the use of direct routing for flights both in cruise and vertically evolving in cross ACC/FIR borders and in high complexity environments to medium complexity environments	n/a	In progress

Reference	Solution name	Local implementation	Synchronised deployment
#33	Free route through the use of free routing for flights both in cruise and vertically evolving in cross ACC/FIR borders and within permanently low to medium complexity environments	n/a	In progress
#34	Digital integrated briefing	n/a	In progress
#35	Meteorological information exchange	n/a	In progress
#37	Extended flight plan In progeess [Synchronised deployment]		
#46	Initial system-wide information management (SWIM) technology solution	n/a	In progress
#51	Enhanced terminal operations with RNP transition to LPV	Slovakia, Montenegro, Cyprus and Malta	n/a
#52	Remote tower for two lowdensity aerodromes	Planned for Germany (Saarbrücken, Erfurt, and Dresden), Norway (15 airports). <i>See also Solution PJ.05-02 on the multiple remote tower module.</i>	n/a
#53	Pre-departure sequencing supported by route planning	n/a	In progress
#54	Flow-based integration of arrival and departure management	n/a	In progress
#56	Enhanced ATFCM slot swapping	n/a	Implemented by NM
#57	User-driven prioritisation process (UDPP) – departure	France, Germany and Switzerland	n/a
#60	Enhanced short-term conflict alert (STCA) for terminal manoeuvring areas (TMAs)	34 countries across Europe	n/a
#61	A low-cost and simple departure data entry panel for the airport controller working position	16 Airports in Germany and continental Spain and on the Canary Islands	n/a
#62	Precision area navigation (P-RNAV) in a complex terminal airspace	13 countries in Europe.	n/a
#63	Multi-sector planning	Italy, Malta, Norway, Poland, Romania and Sweden	n/a
#64	Time-based separation	Heathrow Airport, UK	n/a
#65	User-preferred routing	n/a	In progress
#66	Automated support for dynamic sectorisation	n/a	In progress
#67	AOC data increasing trajectory prediction accuracy	UK (Initial implementation)	n/a
#69	Enhanced short-term conflict alerts (STCA) with downlinked parameters	10 countries across Europe	n/a
#70	Enhanced ground controller situational awareness in all weather conditions	42 airports across Europe	n/a

Reference	Solution name	Local implementation	Synchronised deployment
#71	ATC and AFIS service in a single low-density aerodrome from a remote location	Kiruna from Stockholm RTC (Sweden) Örnsköldsvik, Sundsvall, Linköping and Scandinavian Mountains Airport from Sundsvall RTC (Sweden) Røst, Vardø, Hasvik, Berlevåg from Bodø RTC (Norway)	n/a
PJ.02-01-01	Optimised Runway Delivery on Final Approach	UK	n/a
PJ.02-05	Independent rotorcraft operations at the airports	Austria and Estonia	n/a
PJ.02-08-02	Optimised use of runway configuration for multiple runway airports	France	n/a
PJ.02-08-03	Increased Runway Throughput based on local ROT characterisation	Switzerland and Ireland	n/a
PJ.03a-04	Enhanced visual operations	Sweden	n/a
PJ.05-02	Multiple remote tower module	Planned for Sweden, Norway and Germany	n/a
PJ.06-01	Optimised traffic management to enable free routing in high and very high complexity environments	n/a	In progress
PJ.09-03-02	Collaborative network management functions	Czech republic and Ireland	n/a
PJ.10-01a1	High productivity controller team organisation in en-route (including eTMA) (1PC - 2ECs)	Ireland (Partly)	n/a
PJ.14-03-04	RNP1 reversion based on DME-DME	Lithuania and Poland	n/a
PJ.15-02	E-AMAN Service	France and Spain	
PJ.15-10	Static aeronautical data service	Latvia	n/a
PJ.15-11	Aeronautical digital map service	Latvia (Partly) and Slovakia	n/a
PJ.18-04a	Aeronautical information management (AIM) information	Latvia (Partly) and Slovakia	n/a
PJ.18-04b-01	Meteorological (MET) information-GWMS	Austria and Ireland	n/a
PJ.18-04b-02	Meteorological information (MET) services-Cb-global	Ireland	n/a
PJ.18-02c	eFPL distribution to ATC	n/a	In progress
PJ.18-06b1	NM Trajectory performance improvement	n/a	In progress
#100	ACAS ground monitoring and presentation system	Austria, Czech Republic, Denmark, Hungary and the UK (for post-operational analysis and dashboarding).	n/a

Reference	Solution name	Local implementation	Synchronised deployment
#103	Approach procedures with vertical guidance	Armenia, Croatia, Czech Republic, Hungary, Malta, Montenegro, Luxembourg and Poland	n/a
#104	Sector team operations - en-route air traffic organiser	23 countries across Europe	
#106	Departure manager (DMAN) baseline for integrated AMAN DMAN	29 airports across Europe	
#107	Point merge in complex terminal airspace	Ireland (Dublin), Italy (Milan Bergamo), Spain (Gran Canaria) and the UK (London City and Biggin Hill)	n/a
#108	Arrival management (AMAN) and point merge	France (Paris Charles de Gaulle)	n/a
#110	ADS-B surveillance of aircraft in flight and on the surface	Germany, France, Hungary and the UK	n/a
#113	Optimised low-level instrument flight rules (IFR) routes for rotorcraft	Norway and Switzerland	n/a
#114	Composite Surveillance ADS-B / WAM	Austria and the UK	n/a
#115	Extended projected profile (EPP) availability on the ground	n/a	In progress
#116	De-icing management tool	Austria (Vienna), Belgium (Brussels), Denmark, France (Paris Charles de Gaulle), Germany, Italy and Switzerland (Zurich)	n/a
#117	Reducing Landing Minima in Low Visibility Conditions using Enhanced Flight Vision Systems (EFVS)	France and Sweden	n/a
#118	Basic extended ATC planning (bEAP)	Switzerland and France	n/a

ANNEX 2

Discontinued solutions

The SESAR JU researches and delivers solutions according to a set of agreed business needs and strict performance requirements and with a view to industrialisation readiness. During the course of their development and when assessing the validation results, it may occur that a candidate solution fails to reach the level of expected maturity and performance which in itself is the very purpose and value of R&D. It is during these assessments that a decision may be taken to discontinue research into the solution*. Solutions are also discontinued due to reprioritisation as part of the update of the European ATM Master Plan. Exceptionally, a decision was taken in 2020 to stop work on three solutions due to impact of the COVID crisis on the programme.

SESAR 1	Achieved maturity level	Comment	SJU references
Departure management integrating surface management constraints	V2	The solution has been discontinued given that the expected performance benefits were not validated	#14/Release 5*
Integrated and throughput-optimised sequence of arrivals and departures	V2	The solution has been discontinued given that the expected performance benefits were not validated	#15/ Release 5*
ASAS spacing applications 'remain behind' and 'merge behind'	V2	The solution has been discontinued given that the expected performance benefits were not validated	#16/ Release 5*
Flexible communication avionics	TRL4	The solution content is to be completed by the Clean Sky Joint Undertaking	#112

SESAR 2020 – Wave	Achieved maturity level	Comment	SJU references
Reduction of wake turbulence risk through wake risk monitoring	V2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.02-01-08
Improved parallel operations	V2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.01-03A
Airborne spacing flight deck interval management	V2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.01-05
Approach improvement through assisted visual separation	V2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.01-07
Enhanced navigation accuracy in low-visibility conditions on airport surfaces	TRL4	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.03a-03
Surface operations by remotely-piloted aircraft systems (RPAS)	V2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.03a-09
Conformance monitoring safety nets for pilots	V2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.03b-03
Advanced automated MET system for remote airport	TRL4	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.05-05

Management of performance based free routing in lower airspace	V2	Solution discontinued due to the reprioritization process during the update of the European ATM Master Plan 2020	PJ.06-02
Dynamic airspace configuration supporting moving areas	V0	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.08-02
ACAS for commercial air transport specific operations – ACAS Xo	V0	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.11-A3
Airborne collision avoidance for general aviation and rotorcraft – ACAS Xp	V2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.11-A4
Enhanced ground-based safety nets adapted to future operations	V2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.11-G1
Future communication infrastructure (FCI) air to air functionality	TRL2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.14-02-01b
Development of new services similar to FIS-B to support ADS-B solutions for general aviation	V2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.14-02-05
GBAS Non-MMR avionics architecture	TRL2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.14-03-01c
Multi constellation / multi frequency (MC/MF) GNSS	TRL4	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.14-03-02
SWIM TI common runtime registry	TRL2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.17-08
NM-ATC Flight object interoperability (NM FO IOP)	TRL2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ-18-02b1
Network Manager (NM) trajectory performance improvement	TRL2	Solution discontinued due to the reprioritisation process during the update of the European ATM Master Plan 2020	PJ.18-06b1

SESAR 2020 – Wave 2	Achieved maturity level	Comment	SJU references
Closely spaced parallel runways optimised operations using staggered thresholds (CSPR-ST)	V2	Due to COVID 19 crisis and a significant reduction of planned resources, the solution activities in Wave 2 was discontinued.	PJ.02-W2-14.1
Enhanced arrival procedures using adaptive increased glide slope (A-IGS)	V2	Due to COVID 19 crisis and a significant reduction of planned resources, the solution activities in Wave 2 was discontinued.	PJ.02-W2-14.4
Dynamic pairwise runway separations for departures (based on A/G data exchange)	V1	Due to COVID 19 crisis and a significant reduction of planned resources, the solution activities in Wave 2 was discontinued.	PJ.02-W2-14.12

Glossary

ABSR	Assistant based speech recogniser
ACAS	Airborne collision avoidance system
ACC	Area Control Centre
A-CDM	Airport collaborative decision making
ADDEP	Airport departure data entry panel
ADQ	Aeronautical data quality
ADS-B	Automatic dependent surveillance – broadcast
ADS-C	Automatic dependent surveillance – contract
ADSP	ATM data provider
AEEC	Airlines Electronic Engineering Committee
AeroMACS	Aeronautical mobile airport communication system
AFIS	Aerodrome flight information services
AFUA	Advanced flexible use of airspace
AI	Artificial Intelligence
AIS	Aeronautical information
A-IGS	Adaptive increased glide slope
AIM	Aeronautical information management
AIRM	Aeronautical information reference model
AIXM	Aeronautical information exchange model
AMAN	Arrival manager
ANSP	Airspace navigation service provider
AO	Airport operators
AOC	Airline operational control
AOP	Airport operations plan
A-PNT	Alternative position, navigation and timing
APOC	Airport operations centre
ARES	Airspace reservation/restriction
AROT	Arrival runway occupancy time
ASAS	Airborne separation assistance system
A-SMGCS	Advanced surface movement guidance and control systems
ASPA-IM	Airborne spacing – flight deck interval management
ASR	Automatic speech recognition
ATC	Air traffic control
ATFCM	Advanced short-term air traffic flow capacity management
ATM	Air traffic management
ATN/IPS	Aeronautical telecommunication network internet protocol suite
ATN/OSI	Aeronautical telecommunication network open systems interconnection
ATS	Air traffic services
ATSU	Air traffic control unit
ATV	Air transit view
AU	Airspace user
AUP	Airspace user plan
AUTOMETAR	Automated weather observations
BEAP	Basic extended ATC planning
CAPP	CDTI assisted pilot procedure

CAR	Complexity assessment and resolution
CATC	Conflicting ATC clearances
CAVS	Cockpit assisted visual separation
Cb	Cumulonimbus
CBA	Cost-benefit analysis
CD&R	Conflict detection & resolution
CDA	Continuous descent approach
CDM	Collaborative decision making
CDO	Continuous descent operations
CDTI	Cockpit display of traffic information
CIT	Convectively induced turbulence
CMAP	Conformance monitoring alerts
CNS	Communications, navigation and surveillance
CONOPS	Concept of Operations
COS	Conflict organiser and signaller
CPDLC	Controller-pilot datalink communications
CSPO	Closely spaced parallel runway operations
CSPR	Closely spaced parallel runways
CTA	Controlled time of arrival
CTOT	Calculated take-off times
CVS	Combined vision systems
CWP	Controller working position
DAC	Dynamic airspace configuration
DAPs	Downlinked aircraft parameters
DCB	Dynamic capacity balancing
DF	Deceleration fix
DMAN	Departure manager
DME	Distance measuring equipment
DMIT	De-icing management tool
DPI	Departure planning information
D-PWS-D	Dynamic pairwise separations for departures
DT	Dual thresholds
D-TAXI	Datalink taxi
EAD	European AIS database
E-AMAN	Extended AMAN
EASA	European Aviation Safety Agency
EATMA	European ATM architecture framework
EC	Executive controller
EDIT	Estimated de-icing time
eDME	Enhanced distance measuring equipment
EEZT	Estimated end of de-icing time
EFB	Electronic flight bag
eFDP	Electronic flight data processing
EFPL	Extended flight plan
EFVS	Enhanced flight vision systems
EGNOS	European Geostationary Navigation Overlay Service
EPP	Extended projected profile
ERM	Environment reference material
ESA	European Space Agency
E-TMA	Extended TMA
EU	European Union

EVS	Enhanced vision systems
FAB	Functional Airspace Block
FABEC	Functional Airspace Block Europe Central
FASTI	First ATC support tools implementation
FCI	Future communication infrastructure
FDCI	Flight delay criticality indicator
FDPS	Flight data processing systems
FD-VBC	Fully dynamic virtual block control
FF-ICE	Flight and flow information for the collaborative environment concept
FIR	Flight information region
FIS-B	Flight information system-broadcast
FLDT	Forecasted landing time
FMP	Flow management position
FMS	Flight management system
FOC	Flight operation centre
FRA	Free route airspace
FRT	Fixed radius transition
FTOT	Forecasted take-off time
GANP	Global Air Navigation Plan
GBAS	Ground-based augmentation system
GLS	GBAS landing system
GNSS	Global navigation satellite system
GPS	Global positioning system
GWMS	Ground weather management system
HAIC	High-altitude ice-crystals
HMD	Helmet-mounted display
HMI	Human machine interface
HUD	Heads-up display
i4D	Initial four dimensional trajectory management
ICAO	International Civil Aviation Organization
ICT	Information and communications technology
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IEG	Information exchange gateway
IFR	Instrument flight rules
IGS	Increased glide slope
ILS	Instrument landing system
IOP	Ground-to-ground interoperability
IRS	Inertial reference system
ISRM	Information service reference model
ITF	In-trail follow
ITM	In-trail merge
JU	Joint Undertaking
KPI	Key performance indicators
LDACS	L-band-digital aeronautical communication system
LPV	Localiser performance with vertical guidance
LTE	Long-term evolution
LVC	Low-visibility conditions
MASPS	Minimum aviation system performance standards
MC/MF	Multi-constellation/Multi-frequency
METSPs	Meteorological service providers
ML	Machine Learning

MLAT	Multilateration
MONA	Monitoring aids
MOPS	Minimum operational performance standards
MRS	Minimum radar separation
MRTC	Multi-remote tower centre
MRTM	Multiple remote tower module
MSDF	Multi-sensor data fusion
MSPSR	Multi-static primary surveillance radar
MTCD	Medium-term conflict detection
MTI	Multi touch input
NM	Nautical mile
NM	Network Manager
NOP	Network operations plan
NOTAM	Notice to airmen
NSA	National supervisory authority
NTZ	Non-transgression zone
OBACS	On-board braking action computation system
OLDI	On-line data interchange
OSD	Optimised separation delivery
OTW	Out of the window
PBN	Performance-based navigation
PBS	Performance-based surveillance
PC	Planning controller
PCP	Pilot Common Project
PinS	Point-in-space
PIREP	Pilot air report
PPM	Pulse position modulation
P-RNAV	Precision area navigation
PTZ	Pan tilt zoom
PWS	Pair wise separation
PWS-D	Pair wise separation for departures
R&D	Research and development
RA	Resolution advisory
RAIM	Receiver autonomous integrity monitoring
RECAT	Europe's Wake Vortex Re-Categorisation scheme
REL	Runway entrance lights
RF	Radius-to-fix
RIL	Runway intersection lights
RMAN	Runway manager
RNAV	Required navigation
RNP	Required navigation performance
ROAAS	Runway overrun awareness and alerting system
ROCAT	Runway occupancy time characterisation
ROT	Runway occupancy time
RPAS	Remotely-piloted aircraft systems
RSP	Required surveillance performance
RTA	Required time of arrival
RTC	Remote tower centre
RTS	Remote tower services
RWSL	Runway status light
SATCOM	Satellite communications

SBAS	Satellite-based augmentation systems
SBT	Shared business trajectory
SDPD	Surveillance data processing and distribution
SecRAM	SESAR ATM security risk assessment methodology
SES	Single European Sky
SESAR	Single European Sky ATM Research
SID	Standard instrument departure
SIGMET	Significant meteorological information
SMGCS	Surface movement guidance and control system
SMR	Surface movement radar
SNI	Simultaneous non-interfering operations
SOA	Service-oriented architecture
SPM	Surveillance performance monitoring
SRAP	Second runway aiming point
SRM	Safety reference material
STAM	Short-term ATFM measures
STAR	Standard instrument arrival
STCA	Short-term conflict alert
STM	Surveillance and tracking module
SVS	Synthetic vision systems
SWIM	System-wide information management
SWIM TI	SWIM technical infrastructure
TAM	Total airport management
TBO	Trajectory-based operations
TBS	Time-based separation
TCAS	Traffic alert and collision avoidance system
THL	Take-off hold lights
TMA	Terminal manoeuvring area
TOBT	Target off-block time
TP	Trajectory predictors
TRM	Threat resolution module
TSAT	Target start-up approval time
TSD	Traffic situation display
TTA	Time of arrival
TTL	Time-to-lose
TTOT	Target take-off time
UDPP	User-driven prioritisation process
UPMS	User profile management system
UUP	Updated use plan
VDB	VHF ground-air data broadcast
VLL	Very low level
VoIP	Voice communications over Internet Protocol
VOR	VHF omni range
VPA	Variable profile areas
V-PAT	Vertical flight path analysis
V/AR	Virtual and augmented reality
WAM	Wide area multilateration
WeP	What-else probing
WiMAX	Aviation airport surface datalink system
WOC	Wing operations centre
WVE	Wake vortex encounter



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