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Message from the founding members

Henrik Hololei, Director General, Directorate-General for Mobility and Transport, European Commission, and Chairman of the SESAR Joint Undertaking Administrative Board

The number of passengers passing through the world’s airports will double over the next twenty years at current annual growth rates. Aviation is a hugely important global market and it is important that Europe plays a full role in the sector. In Europe, we need to ensure we can deliver to our citizens more and better connectivity and enable the competitiveness of industry for a sustainable growth.

The SESAR (Single European Sky ATM Research) project has an important role in strengthening the European aviation sector through the modernisation of air traffic management. One of the most important outcomes of the project has been the development of partnerships which link aviation stakeholders in a common desire to maintain and even improve air transport’s safety levels, while making it more punctual, more affordable and all with an improved environmental footprint.

With the establishment of the SESAR Joint Undertaking (SESAR JU) in 2007 by the European Union and Eurocontrol, the ATM community was tasked to develop the technical and operational solutions to overcome fragmentation and meet the performance requirements for the future air traffic management system. The definition and development of these solutions, which are now beginning to be deployed across Europe, is a testament to that original vision of the Single European Sky and SESAR, first articulated by Transport Commissioner Loyola de Palacio in 1999.

This vision has now become a reality thanks to the commitment and collaboration of the ATM community. The following pages illustrate just how complex a challenge this is – but also how deep the reserves of technical and research excellence remain in Europe.

It is only by working more closely together that we will properly be able to exploit these reserves. If we are to meet the targets set for the future performance of the European air traffic management system we will have to ensure that we are at the start, not the end, of a new era of aviation collaboration.
As one of the founding members, Eurocontrol has championed the work of the SESAR JU in bringing about a paradigm shift in ATM and a new way of working together in research and innovation. The solutions described in this catalogue are proof that this change is happening.

European ATM organisations have a long tradition of research and innovation. However, in the years before the Single European Sky was launched it became clear that the resources needed for all the intended research was not enough and that duplication was hampering the outcomes. A greater focus on modernisation under one roof and with validations much closer to real operational environments required a deeper involvement of the broader aviation and ATM industry. We have come a long way since the establishment of the SESAR JU. In SESAR we have now established a framework for research cooperation which is breaking down “silos” and bringing together all ATM stakeholders, from airspace users, air navigation service providers to airports, manufacturers, military, professional staff associations, research institutes and academia.

We wholeheartedly believe and subscribe to this approach which is why we have concentrated all our development resources and work within the SESAR project. In particular, we have taken the lead in those solutions with a pan-European network dimension, from free routing and advanced flexible airspace use to the network operations planning and the move towards trajectory-based operations. We are confident that these solutions will enable us to meet the performance ambitions of the coming years.

We are particularly proud of our role in building and maintaining the European ATM Master Plan, which has been key to achieving consensus in all stages of the ATM lifecycle, from definition and development through to deployment. Thanks to the Master Plan, we now have a clear link between research and deployment, ensuring that the solutions developed and validated by the SESAR JU are deployable in the real operational world of aviation and ATM. The fact that some of the solutions in this catalogue are already implemented or in the process of being deployed is proof that we are moving in the right direction.
Foreword

Florian Guillermet,
Executive Director,
SESAR Joint Undertaking

This first edition of the Catalogue draws together 63 SESAR Solutions delivered by SESAR JU members and partners to modernise Europe’s air traffic management system. Developed in line with the European ATM Master Plan - the main planning tool for ATM modernisation - these solutions serve as a basis for deployment activities and further research in SESAR 2020.

Long lead times often mean that change in ATM happens at a slow pace. And yet in a relatively short space of time, the SESAR JU has succeeded in bringing together more than 100 organisations and 3,000 experts from the entire ATM community to fast track the delivery of tangible performance-based solutions, validated, documented, packaged and publically available for implementation by industry partners. The solutions range from the technological and operational to those underpinning the foundations of our work. Some are already implemented, addressing gaps in the current ATM system thereby demonstrating the rationale for the establishment of SESAR.

The contents of this catalogue are evidence of how European R&I are concretely delivering against European performance targets. Whether implemented individually or in combination, the solutions can bring benefits in key performance areas, such as cost and operational efficiency, capacity, safety, security and the environment. This is in keeping with the European ATM Master Plan, which recognises the wider context of the need for interoperability and linking technologies to achieve greater efficiency across the whole network; for example targeting improvements across an entire flight rather than in segments. And this reflects the change in mindset that the SESAR JU has helped to introduce through its unique public and private partnership structure.

The contents of this first edition range from baseline or quick-win solutions to those that address more complex operations. They cover solutions which have been fully validated and documented, with the majority confirmed as ready for implementation. Stakeholders have already taken steps to implement some of these into their operations. We have also delivered a set of these solutions to the SESAR Deployment Manager, which is preparing their synchronised and timely deployment across Europe over the next five years. This catalogue is a living document and will be updated in the future as more solutions become ready for industrialisation and deployment within the framework of SESAR 2020.
SESAR in a nutshell

The Single European Sky ATM Research (SESAR) project, set up in 2004 as the technological pillar of the Single European Sky to modernise Europe’s air traffic management (ATM) system, is now making significant progress in transforming the performance of Europe’s ATM network. The goal of SESAR is to contribute to the SES High-Level Goals of tripling capacity, halving costs per flight by 50 %, reducing emissions by 10 % and improving safety by a factor of 10.

Established in 2007, the SESAR JU, a public-private partnership, is responsible for defining, developing and validating these solutions in preparation for their deployment. The SESAR JU does so by harnessing the research and innovation expertise and resources of the entire ATM community, from the Network Manager and civil and military air navigation service providers, to airports, civil and military airspace users, staff associations, academia and research centres.

The following pages bring together in one volume the 63 validated and documented SESAR Solutions delivered by the first wave of research and innovation (SESAR 1). Framed within the European ATM Master Plan, these solutions address all parts of the ATM value chain, from airports, air traffic services to the network, as well as the underlying systems architectures and technological enablers, which are validated in real day-to-day operations. On every page you will find evidence of how SESAR is contributing to improved ATM performance.

Several of these solutions are already in operation, demonstrating SESAR’s role in transforming Europe’s ATM network into a modern, cohesive and performance-based operational system. Further proof of the readiness of SESAR R&I is the decision by the European Commission to package a first set of SESAR Solutions into a Pilot Common Project (PCP)¹, which are ready for industrialisation and for synchronised deployment across Europe. The SESAR Deployment Programme, which is managed by the SESAR Deployment Manager, is working to ensure that solutions delivered by the SESAR JU enter into everyday operations across Europe, resulting in significant benefits for airspace users and the environment. This means that Europe is well on its way to building the ATM system that it needs to increase the performance and sustainability of its aviation sector.

¹ European Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan Text with EEA relevance
What are SESAR Solutions?

SESAR Solutions refer to new or improved operational procedures or technologies that aim to contribute to the modernisation of the European and global ATM system. Each solution includes a range of documentation, including:

- Operational services and environment descriptions;
- Safety, performance and interoperability requirements;
- Technical specifications;
- Regulatory recommendations;
- Safety and security assessments;
- Human and environmental performance reports.

To deliver solutions for deployment, the SESAR JU and its members have built a process, known as the release process, whereby solutions are tested or validated in real operational environments including direct airport interfaces. With validation sites across Europe, the SESAR JU and its members have taken R&I out of the lab and connected it with the real world.

Validations take place in simulation platforms, on board commercial flights, dedicated airport testbeds and air traffic control centres. Exercises are not limited to a specific location, but can be used to test multiple environments irrespective of the location where the physical validation is held.

To date, over 350 validations have taken place, where pilots, controllers, engineers and other operational staff have worked with SESAR projects to put the solutions to the test.

**SOLUTION STATUS**

The validation of the majority of the solutions has been completed, while work is planned to finalise a number of solutions. The status of the solutions is indicated on each page with one of the following icons:

- The solution is **ready** for industrialisation or implementation has already started.
- This solution is in the pipeline for delivery. Further validation work is planned to finalise the solution.
### SESAR validation techniques and tools

A number of techniques and tools are used to validate the SESAR Solutions, sometimes in combination with one another. These include:

**Fast-time simulations:** involve using models of ATM systems, several of which exist for both airspace and airport operations. These models are highly dependent on the data used to drive them, and hence must be carefully validated in order to assure realistic outputs. They are best used to test the sensitivity of a proposed solution to different assumptions and scenarios.

**Real-time simulations:** provide human-in-the-loop experience of a proposed solution in a relatively controlled and repeatable environment. Data collected may include simulator data logs, observer notes, video recordings, questionnaires and debriefing sessions.

**Shadow-mode trials:** involve the use of prototypes of operational tools to assess the effectiveness of a proposed solution. The prototypes are integrated with live operational systems and run in the background in parallel.

**Live trials:** involve the deployment of prototypes of operational tools and/or the use of proposed procedures in live operation. They have the advantage of exposing the proposed solution to reality but inevitably place high demands on rigorous safety assessment and understanding the effects (positive and negative) on impacted traffic.

**Demonstrations:** bring together a broader range of stakeholders from airlines, air navigation service providers, to the manufacturing industry and airports in order to demonstrate the benefits of SESAR solutions in real-life environments using commercial flights.

SOURCE: European Operational Concept Validation Methodology (EOCVM)
FIGURE 1 — Locations where solutions have been validated
Addressing the needs of the entire ATM community

SESAR Solutions have been categorised according to four key areas of ATM (key features):

**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 normal conditions, and through the further development of collaborative recovery procedures in adverse conditions. In this context, this feature addresses the enhancement of runway throughput, integrated surface management, airport safety nets and total airport management.

**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.

**Optimised ATM network services**

An optimised ATM network must be robust and resilient to a whole range of disruptions, including meteorological and unplanned events relying on a dynamic and collaborative mechanism. This will allow for a common, updated, consistent and accurate plan that provides reference information to all planning and executing ATM actors. 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) via system-wide information management (SWIM).

**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.

**WHO BENEFITS?**

SESAR Solutions meet the business needs of a range of ATM stakeholders. For each solution, the stakeholders targeted by the solution are indicated using the following key:

- **ANSP**: Airspace navigation service providers (civil and military)
- **AO**: Airport operators (civil and military)
- **AU**: Airspace users (civil and military)
- **NM**: Network Manager
Delivering performance

Performance is at the heart of SESAR, which is why every SESAR Solution is assessed and documented according to a set of key performance areas, notably safety, cost efficiency, operational efficiency, capacity, environment, security and human performance. Some solutions bring specific local value, for example the introduction of remote tower services at small regional airports. Others are organised to deliver benefits in a synchronised manner across Europe. The performance of SESAR Solutions validated in SESAR 1, many of which are captured in this catalogue, can be measured as follows:

3 Improved predictability: measured by the variability in the duration of the flight;
3 Reduced costs: refers to the costs associated with air navigation service provision;
3 Increased airport capacity: refers to runway throughput at 'best-in-class' airports which already operate close to their capacity limit;
3 Increased airspace capacity: refers to airspace which is close to saturation in both en-route and in the surrounding area of airports (terminal manoeuvring area);
3 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).

FIGURE 2 — SESAR 1 performance results

* Corresponding to a reduction of the standard deviation between actual and scheduled flight time from 7.4 to 6.1 minutes.

(2) Source: 2015 Performance Assessment [B.5-D71]. The figures refer to the performance assessment made on all the SESAR results captured by 2015 relative to the 2005 baseline. This includes solutions which are ready for industrialisation [V3], solutions for which more work is planned under SESAR 2020 (V2) and developments with regard the deployment baseline.
Framing SESAR Solutions

SESAR Solutions are very much the end product of the SESAR research and innovation pipeline. However, these solutions would not see the light of day if it were not for a number of important transversal elements and activities that support and frame the operational and technological work. These transversal elements, working in the shadows of the programme, ensure that the end products fully fit with the SESAR vision and meet the necessary criteria, whether they have to do with the system, service and operational architectures, the key performance ambitions or the required cost-benefit analysis and business case. These elements are complementary to one another and are regularly reviewed to ensure alignment with the SESAR vision.

Seeing the big picture

European ATM Master Plan

Set within the framework of the Single European Sky (SES), the Master Plan is the European planning tool for defining ATM modernisation priorities and ensuring SESAR Solutions become a reality. Both pragmatic and ambitious in its design, the Plan provides a high-level view of what is needed in order to deliver a high-performing aviation system for Europe. It also sets the framework for the related development and deployment activities, thereby ensuring that all phases of the SESAR lifecycle remain connected. The content of the Master Plan is structured into three levels, allowing stakeholders to view the information that is most relevant for them whether they are executives, planners or those implementing the plan. The Plan is accessible online via https://www.eatmportal.eu.

SESAR Concept of Operations

The Master Plan is supported by the SESAR Concept of Operations (CONOPS). It describes the operational target, namely to move ATM towards business or mission trajectory-based operations. The CONOPS allows all those in ATM, from the civil and military airspace users and service providers, to airports and the manufacturing industry to gain a common understanding of the system and a clear view of the phases to achieve the concept target. The SESAR CONOPS, which has been adapted for Europe from the ICAO Global Air Traffic Management Operational Concept, is an important reference for global interoperability and harmonisation.

SESAR system and services architecture

To meet the operational needs described in the CONOPs, SESAR has developed and described an overall technical architecture of the ATM system that highlights interconnectivity between the various technical systems through system-wide information management (SWIM) and message exchange interfaces. This is captured in the architecture description document, which is the entry point to more detailed architectural information hosted in the European ATM architecture (EATMA) framework.
European ATM Architecture (EATMA)

The EATMA is a repository of content and programme-related information that provides the structure to the work of the 300 projects that have made up the first SESAR R&I activities (SESAR 1). In doing so, the EATMA ensures a coherent architecture framework for developing interoperable solutions, as well as for identifying gaps or duplication of technical system work between projects. As a framework, the EATMA federates the performance framework as well as operational, systems and service architectures. The EATMA is accessible through the ATM Master Plan portal that captures, maintains, validates and reports on architecture-related content.

Information exchange at your service

SWIM is about sharing the right information with the right people at the right time. The SESAR SWIM framework lays down the core principles of SWIM, which consists of standards, infrastructure and governance enabling the management of ATM and its exchange between stakeholders via interoperable services. SWIM is structured around three main layers:

1. Information: Aeronautical information reference model (AIRM)
2. Services: Information service reference model (ISRM)

All of these layers require appropriate standards to ensure interoperability. On top of these layers a transparent governance structure manages the development, deployment and evolution of these SWIM building blocks.

Making the case

Meeting the performance ambitions

Performance is the heart of the Single European Sky and therefore SESAR’s work. It is no surprise then that the SESAR JU has integrated a framework to measure the performance SESAR Solutions and aggregate the results to the level of the Master
Plan. This approach means that at the very outset, SESAR Solutions are designed with a range of performance ambitions in mind (operational and cost efficiency, capacity, safety, environment, security), aimed at contributing in a measurable way to reaching the SES performance targets and, in the long term, the SES High-Level Goals. The framework and process also allow for the traceability of performance throughout the development of the solutions until their delivery. Regular performance assessments are made providing the detailed calculations, assumptions and gap analysis for SESAR Solutions. The bottom-up results stemming from individual analysis on the different Solutions are then consolidated at a higher level to provide a holistic view of the performance of SESAR and to identify possible performance gaps.

**Supporting methodologies**

Supporting methodologies form part of the backbone of any R&I programme, since they ensure that a common approach to testing and analysis. In SESAR 1, a range of methodologies has been developed to support assessments of solutions. These assessments provide input to cost-benefit analysis and the overall business case of a solution. They also allow for forward and backward traceability between R&I and the High-Level Goals of the SES.

**Safety:** enables safety assessments to be carried out across the programme in a systematic way. The methodology framework is also validated by the European Aviation Safety Agency (EASA). It is documented in the safety reference material (SRM) and is based on a rigorous requirements-engineering (RE) approach.

**Security:** provides a holistic approach to assess ATM security, addressing personnel, procedures and the physical infrastructure, as well as information and communications technology (ICT) systems. The approach is documented in the SESAR ATM security risk assessment methodology (SecRAM) and can be applied in a tailored manner to the projects developing solutions. The methodology consists of several catalogues containing security assets (information and services) and controls that can be selected to mitigate risks. In addition the methodology uses a specialised database in which to store results for analysis and to automatically generate reports.

**Human performance:** ensures that human performance-related aspects are systematically identified and managed during the definition, development and validation of solutions. The methodology provides projects with a framework in which to assess whether a solution will contribute to expected human performance benefits and is within the scope of human capabilities and limitations.

**Environment:** offers a common approach to making the environmental impact assessments of solutions. The process, captured in a document called environment reference material (ERM), is derived from a mapping onto the SESAR validation framework of the globally-recognised process from ICAO. The methodology provides guidance at each step of the validation process of a particular solution, indicating, for instance, types of environmental impact that should be assessed, and when and how they should be assessed. The methodology includes tools for assessing a solution’s impact in terms of noise and fuel and emissions (IMPACT); local as well as global fuel and emissions (AEM); airport fuel and emissions and dispersion (Open-ALAQS); and for vertical flight path analysis (V-PAT). It should be noted that these tools have also been developed to be used for the research and future deployment phase of SESAR. The methodology also contains an appendix describing the assessment of fuel efficiency based on aircraft-derived data from flight trials, one of the main validation techniques used by the SESAR R&I programme.

**Cost-benefit analysis (CBA) and business case development:** provides an approach and common guidance to structure, organise and validate the many contributions stemming from the active involvement and support of all ATM stakeholder groups in

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defining the economic, financial and business impact of SESAR. The reference material goes beyond strict CBA models and includes also the method to assess costs and to identify, structure and monetise the benefits in the validation activities. The solution integrates several different models including scheduled airlines, business aviation, general aviation, rotorcraft, ANSPs and airports as well as a cost model for the military.

It should be noted that these methodologies are valid under SESAR 1 and will evolve under SESAR 2020 with a view to closing the gap between the SESAR performance framework and the SES performance framework. Commission implementing Regulation (EU) No 409/2013 has established that SESAR deployment is ‘essential to achieve the SES performance objectives’ and that ‘common projects shall be consistent with and contribute to the European Union-wide performance targets’. Thus, the definition and assessment of the performance ambitions and validated results of the SESAR Solutions need to be aligned and cross-readable with the SES performance framework, key performance areas and indicators. This has already been done in 2015 edition of the Master Plan.

Roadmaps and strategies

Communications, navigation and surveillance (CNS) roadmaps

CNS technologies on the ground and on board the aircraft are an essential underlying technical enabler for many of the operational improvements and new procedures of the future ATM system. Performance requirements for CNS systems are becoming increasingly complex and demanding and will be considered as part of an integrated air and ground CNS system, whereby convergence towards common infrastructure components may be considered, where appropriate, across the different CNS domains. In parallel, CNS systems and both airborne and ground infrastructure will take a more business-oriented approach that sees a more efficient use of resources, delivering the required capability in a cost-effective and spectrum-efficient manner.

These factors are taken into account in the CNS Roadmaps that provide a detailed vision of the European infrastructure evolution described in the European ATM Master Plan to support the evolving SESAR Target Concept (short, medium and long-term). It covers the airborne and ground communication, navigation, surveillance, as well as the spectrum aspects, in an integrated perspective, starting from the current baseline and driven by updated strategy and planning information from the stakeholders.

Spectrum Strategy

Radio spectrum is vital for safe, efficient and cost-efficient air transport, and in particular for enabling the provision of CNS. The SESAR Spectrum Strategy’s main goal is to create a sustainable environment for spectrum-efficient aeronautical systems. It does so by identifying the means to optimise the current spectrum usage as well as developing more spectrum-efficient CNS technologies. Work is underway to integrate the SESAR strategy into the ICAO Handbook on Radio Frequency Spectrum Requirements for Civil Aviation Doc 9718 Vol 1 ICAO spectrum strategy, policy statements and related information. The strategy examines potential spectrum requirements, beyond existing strategic plans, in the timeframe 2035-2050 based on the European aviation vision set out in Flightpath 2050 (FP2050).
Solutions at a click of the button

The value of SESAR Solutions is dependent on the ability of the aviation industry to move forward with their implementation. For every validated solution, there is a significant amount of documentation on the deliverables required for their industrialisation. Each solution comes with recommendations on the regulatory and standardisation frameworks needed. This documentation has been assembled in the SESAR Solution Packs and made available online to allow that a much wider audience obtain the information they need.

The Solution Packs are displayed in three steps:

3 **At a glance:** gives a brief description of the solution and the benefits it will bring to air traffic management

3 **In context:** provides a summary of the validation process, performance achievements, benefits to ATM operations, and activities to be conducted before or as part of deployment

3 **Getting technical:** provides a pack of reference documentation, including operational services and environment descriptions, safety, performance and interoperability requirements, technical specifications, standards and regulatory recommendations. Additional material may include safety and security assessments, and human and environmental performance reports.

The SESAR Solution Packs enable the entire ATM community to actively explore how they can best benefit from SESAR Solutions, according to their own needs, to ensure that these solutions become a reality. This Catalogue is complementary to the solution packs, offering a reference for stakeholders in order to pick and choose the solutions that are most relevant for their business.

Visit the SESAR Solution portal: www.sesarju.eu/solutions
High-performing airport operations
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.

Over 90 flights were conducted using several prototype systems, and the results are being used to help develop common standards at an international level. The work continues in parallel with the development of airborne GNSS landing system (GLS), the avionics required for GBAS-controlled landings. Assuming that standardisation and regulation progress as planned, the entry into service of GBAS Category II/III is expected in the 2018-2019 timeframe.
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 five additional aircraft landings with TBS per hour compared to traditional distance-based separation procedures. TBS results in an average reduction of 0.9 minutes holding time, and an average reduction of 1.4 minutes between stack-entry and touchdown times.

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

The SESAR Solution is available for industrialisation. TBS entered into full-time service at London-Heathrow in March 2015. The solution is due for synchronised deployment across Europe in accordance with the Pilot Common Project.
EFFICIENT PLANNING AROUND THE AIRPORT

Automated assistance to controllers for surface movement planning and routing

Selecting the most suitable route from the departure gate to the runway depends on the airport layout, aircraft type, operational constraints such as closed taxiways, arrival routes, as well as departure planning information such as target start-up times.

The SESAR surface route planner 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 (cockpit display system or airport moving map) 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 manual routing. Efficiency of surface operations is also improved since pilots and vehicle drivers can receive optimum route plans. Safety and capacity are also enhanced as a result of more predictable operations.

This solution is in the pipeline for delivery. The solution is due for synchronised deployment across Europe in accordance with the Pilot Common Project.
STAKEHOLDERS

AO  ANSP  AU  NM

IMPROVED COMMUNICATIONS THANKS TO DATALINK

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

Radio channels become congested and hard to access during busy departure times. 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 of planned and cleared departure routes by datalink 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 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 predictability of surface movements.

This solution is in the pipeline for delivery.

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
- Reduced fuel burn and emissions

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

Any non-safety critical surface routing requests from flight crews including ATC-flight crew negotiations via datalink are part of the D-TAXI service

High-performing airport operations 25
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.

This solution is in the pipeline for delivery.
FOLLOW-THE-GREENS
Guidance assistance through airfield ground lighting

Airfield ground lighting offers a unique opportunity to guide aircraft 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 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 as the aircraft moves along its assigned route. Stop bars are automatically activated at no-go areas, and the pilot simply receives a single instruction to ‘follow-the-greens’. The activity 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.

SESAR validations have 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 in the pipeline for delivery.
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, 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 help the ground controller provide 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. Similarly, for aircraft equipped with datalink, the location of virtual stop bars can be uplinked to the airport moving map. 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 and improves predictability of surface movements. Taxi times improve and variability are reduced in low-visibility conditions, thereby reducing fuel burn and emissions.

Real time simulations tested the solution using datalink communications with aircraft as well as airfield vehicles.

This solution is in the pipeline for delivery.
ENHANCING SAFETY AT BUSY AIRPORTS

Airport safety nets for controllers: conformance monitoring alerts and conflict detection

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 simulations to see how various tools can operate together to provide integrated airport safety nets. These simulations 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 cleared route deviation by aircraft.

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 the current practise of relying on surveillance data to trigger an alarm. Taxi route deviations are among the most common alerts at large busy airports, but all alerts improve safety.

This solution is in the pipeline for delivery. Airport safety nets are due for synchronised deployment across Europe in accordance with the Pilot Common Project.
SURFACE SAFETY IN ALL WEATHER CONDITIONS

Enhanced ground controller situational awareness in all weather conditions

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.

BENEFITS

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

STATUS

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

STAKEHOLDERS

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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 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 the instant a potential incursion is detected by the A-SMGCS.

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 runway incursions. It applies equally to aircraft and vehicle traffic and does not require additional equipment in the cockpit or driver’s cab.

This solution is in the pipeline for delivery.
PROVIDING VEHICLE DRIVERS WITH ENHANCED VISUAL TOOLS

Enhanced traffic situational awareness for vehicle drivers

Driving an airfield vehicle around 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 controller’s surface guidance system.

The trials confirmed 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 in the pipeline for delivery.

This activity aims to develop and validate support tools to prevent runway incursions and deviations from ATC instructions by vehicle drivers
A BASELINE FOR ON-TIME DEPARTURE

Departure manager (DMAN) baseline for integrated AMAN DMAN

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 14.6kg of fuel per flight, and also supports enhanced tactical scheduling.

The solution has been implemented at Paris Charles de Gaulle Airport and is due to be deployed as part of the Pilot Common Project.

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

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)

STAKEHOLDERS
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- AO
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STATUS

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SJU references:
#106/Release 1
IMPROVING ON-TIME DEPARTURE

Pre-departure sequencing supported by route planning

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 planned for deployment across Europe in accordance with the Pilot Common Project.
A COORDINATED DEPARTURE ROUTE

Departure management integrating surface management constraints

The departure manager (DMAN) takes inputs from a number of different sources to calculate the optimum sequence for aircraft to push back from the gate and taxi to the runway. The process may begin hours before a flight is due to depart, when flight plan data, flow management slots, and aircraft schedules provide a reasonable guide to departure time.

The calculation becomes a lot more precise if tactical information is added into the equation. For example, the taxi out time from the gate to the runway may change by several minutes depending upon the route available; arriving aircraft can slow down the rate of departure; and busy taxiways will also affect route planning by the tower controller. Taking account of these variables, the DMAN is able to estimate more precise departure times, and calculate a more accurate pre-departure sequence for aircraft at the gate. This keeps taxi times down, and reduces fuel burn and emissions.

This solution builds on validation activities carried out for basic DMAN combined with route planning (see solution ‘pre-departure sequencing supported by route planning’). The exercises showed how accurate pre-departure sequences help to reduce waiting time at the runway holding point and improve adherence to target take-off time.

The solution integrates surface planning and routing functions to build a very accurate departure sequence, taking the tactical changes into account. The solution includes procedures and technical specifications to support the addition of dynamic data from the control tower, in particular to take account of taxi-out times. Integrating surface management constraints with departure management delivers a more predictable departure sequence, and improving the use of available capacity on the airfield. Safety is also enhanced by reducing the risk of unplanned events.

This solution is in the pipeline for delivery and is part of synchronised deployment plans for Europe in accordance with the Pilot Common Project.
EXTENDING THE PLANNING HORIZON
Flow-based integration of arrival and departure management

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.

The solution is available for industrialisation.
It is common for arriving aircraft to take priority at an airport, but with careful planning, traffic flow can be optimised for both arrivals and departures. By integrating the sequence of arrivals and departures, and adjusting the traffic flows to minimise delays, overall efficiency can be improved.

The solution requires the departure manager (DMAN) to be coupled with the arrival manager (AMAN). An algorithm ensures minimum separations are maintained, and up-to-date information regarding the pre-departure sequence and the arrival metering sequence is used to calculate the optimum traffic flow. Controllers play an important part in working towards establishing the plan, for example by following target take-off times and target landing times as closely as possible. Planners create gaps in the arrival sequence to allow for departure flights. The process is particularly useful at busy single runway airports, or with dependent runways, where both capacity and efficiency can improve as a result of using integrated systems.

Real-time simulations assessed the feasibility of integrating AMAN-DMAN, and its impact on runway throughput, airport operations and service provision. Operational and human factor issues that can affect performance were also looked at. Controller tools such as route planning, surface conflict alerts, and flight data were included in the sequence planning.

This solution is in the pipeline for delivery.
REMOTE TOWER SERVICES FOR SMALL AIRPORTS
ATC and AFIS service in a single low-density aerodrome from a remote controller working position (CWP)

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, and two more regional airports are implementing similar technology.

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 currently match those for real operations and approval is based on the same service delivery requirements as existing ICAO rules

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

STATUS

ANS
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SJU references:
#71/Release 3
REMOTE TOWER SERVICES
BENEFIT MEDIUM-SIZED AIRPORTS

Single remote tower operations for medium traffic volumes

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.

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.

This solution is in the pipeline for delivery.
MANAGING MULTIPLE SMALL AIRPORTS, REMOTELY
Remote tower for two low-density aerodromes

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. Norway plans to deliver aeronautical flight information services to five small airports from one central facility at Bodø starting in 2017.

BENEFITS
- Operational and technology-related cost efficiency

STATUS

NJU references: #52/Release 4
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.

This solution is in the pipeline for delivery.
LINKING SMALL AIRPORTS TO THE NETWORK

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

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 available for industrialisation. The solution has been deployed in several locations, in particular in the UK.

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

STATUS

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.
STAKEHOLDERS

43 High-performing airport operations

STATUS

AIRPORTS ARE THE NODES OF THE NETWORK

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).

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. Four principle tasks are covered in these solutions: to establish performance goals, to monitor these goals, to take action if performance deviates, and to provide feedback and analysis on actions taken.

Ultimately, the AOP and APOC make airports more resilient to disruptions, allowing a more efficient management of airport demand capacity balancing and operations such as de-icing.

SESAR validations looked in detail at information requirements, alerts and information sharing in order to optimise runway use during capacity-constrained situations. Real-time simulations as well as shadow-mode exercises were used to validate airport performance monitoring and management. Finally, a live trial took place using a de-icing management tool to review performance in winter conditions.

In 2014, London Heathrow and Paris Charles de Gaulle partially implemented the solution. The full solution is in the pipeline for delivery and synchronised deployment is planned as part of the European Commission’s Pilot Common Project.

BENEFITS

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

This solution offers services to steer, monitor and manage airport performance

STATUS

PCP

High-performing airport operations
Advanced air traffic services
ASSIGNING HOLDING STACKS TO HISTORY

Extended arrival management (AMAN) horizon

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, the solution is due to be deployed across Europe in accordance with the Pilot Common Project.

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

London-Heathrow has cut holding times in its arrival stacks by one minute, reducing noise emissions and saving airlines over EUR 2 million in fuel bills and 7 500 tonnes of carbon dioxide annually.
IMPROVING ARRIVAL EFFICIENCY AND PREDICTABILITY

Point merge in complex terminal airspace

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.

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.

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.

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’s Dublin Airport, Oslo in Norway and the Canary Islands.

BENEFITS

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

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

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

STATUS

ANSP
AO
AU
NM

SJU references:
#107/Release 2

IMPROVING ARRIVAL EFFICIENCY AND PREDICTABILITY

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SJU references:
#107/Release 2
ELIMINATING HOLDING PATTERNS IN THE EXTENDED TERMINAL AREA

Arrival management (AMAN) and point merge

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 performance-based navigation (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 available for industrialisation. Following SESAR validations, the solution has been put into operation in several large European airports such as Paris Charles de Gaulle.
SMOOTHER, QUIETER, AND MORE EFFICIENT

Continuous descent operations (CDO) using point merge

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.

During the validation of the solution, aircraft were vectored to a common merge point from where they could follow a single air navigation trajectory [RNAV] procedure to intercept the instrument landing system (ILS). This enabled pilots to select the optimum descent path, as calculated by the onboard flight management computer, based on aircraft type, load, and wind speed. This also allows for multiple CDOs to be carried out for smoother, quieter descents to the runway.

CDOs are an example of a ‘win-win’ solution since no levelling off is needed, aircraft burn less fuel. They also can climb much higher thereby reducing the noise impact for the areas below. Initial results showed that noise levels for inhabitants living near the airport changed as controllers were able to disperse arrival paths and positioned the RNAV trajectory away from populated areas. 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.

This solution is in the pipeline for delivery.
FLYING MORE EFFICIENT ROUTES
Precision area navigation (P-RNAV) in a complex terminal airspace

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 already implemented in several airports, including Madrid. The solution is to be deployed in accordance with the Pilot Common Project.
DESIGNING MORE EFFICIENT AIRSPACE

Optimised route network using advanced required navigation performance (RNP)

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 TMAs 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.

The solution is available for industrialisation.
FLEXIBLE ARRIVALS
AND DEPARTURES
Enhanced terminal operations with RNP transition to ILS/GLS

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 due to be implemented across Europe in accordance with the Pilot Common Project.

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

STATUS

Advanced RNP procedures improve access to busy airports, help to maintain all-weather operations, and reduce environmental impact
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 1 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 available for industrialisation. Enhanced terminal operations with LPV procedures are planned for synchronised deployment across Europe in accordance with the Pilot Common Project.
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.

By the end of 2015, more than 250 LPV procedures had been published across Europe, and the number continues to rise sharply. The new procedures have enabled some states to decommission ILS services at some regional airports, saving costs.

The solution is available for industrialisation and is due for synchronised deployment in accordance with the Pilot Common Project.
STREAMLINING TRAFFIC FLOW INTO MULTIPLE AIRPORTS

Arrival management into multiple airports

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.

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.

This solution is in the pipeline for delivery.
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, the flight management system will optimise the flight speed according to aircraft type and wind conditions.

SESAR is testing 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. Adding the procedure to the arrival management process will contribute to more stable arrival sequences at an earlier stage, and reduce the environmental impact. Integration of this solution with other solutions, such as extended arrival management (E-AMAN) and/or airborne sequencing and merging, is under validation to consolidate a larger set of benefits in the arrival queue management operations.

This solution is in the pipeline for delivery. Further work is planned in particular to consolidate the results and requirements to support implementation.
AIRCRAFT SPACING TOOLS TO STABILISE ARRIVAL MANAGEMENT

ASAS spacing applications ‘remain behind’ and ‘merge behind’

The management of traffic flows in almost all European terminal manoeuvring areas (TMAs) requires complex traffic patterns and tactical intervention e.g. open-loop vectoring. This impacts the overall ATM system performance (capacity, predictability, efficiency).

By using the aircraft’s on-board airborne separation assistance system (ASAS) to monitor distances between aircraft, the flight deck can maintain the spacing requested by air traffic control. Separation provision is still the controller’s responsibility, but the pilot would only need one instruction – for example “remain 90 seconds behind” – rather than several speed commands by the controller. On-board automation would automatically generate and execute the appropriate speed commands.

SESAR is assessing the application of airborne interval management sequencing and merging during the arrival phase for ADS-B-in-equipped aircraft.

A combination of flight trials and real-time simulations aim to demonstrate the compatibility between airborne spacing interval management and controlled time of arrival operations.

This solution is in the pipeline for delivery.

BENEFITS
- Enhanced safety
- Increased capacity in the TMA

To carry out airborne sequencing and merging, an aircraft has to be equipped with ADS-B-in, a traffic situational awareness tool, interval management capability, and advanced required navigation performance capabilities.

The ASAS sequencing and merging applications require the flight crew to achieve and maintain a given spacing with designated aircraft, as specified in a new air traffic control instruction. Although the flight crew is given the new task, separation provision is still the controller’s responsibility and applicable separation minima are unchanged.
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 visuals 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.
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.

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.

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.

The solution is available for industrialisation.
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.

Earlier, more reliable and accurate conflict detection leads to better decision making and fewer tactical interventions by controllers. This SESAR solution proposes features specific to the planner controller (PC) or to the tactical controller (TC) in order to cover their specificities when managing high-complexity airspace operations in the en-route environment. The solution focuses on conflict detection aids to TC/PC showing all detected conflicts that would result in a conflict if the controller does not initiate an action, in particular the monitoring aids (MONA) service and the what-else probing (WeP). These tools optimise air navigation service productivity.

A series of real-time simulations are being used to validate tactical and deviation trajectory, ‘what-if’ and ‘what-else’ probes, medium-term conflict detection (MTCD), and MONA functionalities.

Real-time simulations are assessing the operational acceptability of automated tools in a free route environment, including a conflict detection function which identifies conflicts up to 20 minutes in advance, called conflict organiser and signaller (COS). Within these exercises, assessments will be made on how flight trajectory sharing can improve the coordination of tasks and controller assistance services between ground control centres.

The SESAR work focuses on the distribution of tasks between planner and tactical controllers, and how the tools are integrated into the decision-making process. The more advanced tools rely on an aircraft’s 4-dimensional (4D) trajectory prediction capability, and their synchronisation with route clearances issued from the ground. This includes the exchange of 4D clearances and intent information such as lateral, longitudinal, vertical speed and time constraints.

This solution is in the pipeline for delivery.
ALLOWING USERS TO CHOOSE THEIR ROUTE

User-preferred routing

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 Maastricht Upper Area Control centre now offers more than 250 user-preferred routes and has recorded an average 7% reduction in flight distance flown – or two minutes less flight time – by participating aircraft, while lower fuel consumption has seen emissions fall between 6 and 12%.

The solution is available for industrialisation and is due to be deployed in accordance with the Pilot Common Project.
MORE DIRECT ROUTES FOR CROSS-BORDER OPERATIONS

Free route through the use of direct routing

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.

This solution is in the pipeline for delivery and is due for implementation across the whole of Europe’s upper airspace in accordance with the Pilot Common Project.
EUROPE-WIDE FREE ROUTING
Free routing for flights both in cruise and vertically-evolving above a specified flight level in low-to-medium density airspace

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.

This solution is in the pipeline for delivery and is due to be deployed across the whole of Europe’s upper airspace in accordance with the Pilot Common Project.

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

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

Status: EETT UDDD EISN LWSS LRBB LIPP LFRR EKDK LJLA EPWW LPPO EGGX LPPC EVRR LUUU LDZO LKAA LOVV LFBB EFIN ESOS LYBA EGTT UGGG ESMM EDUU LSAZ LIMM LBSR EYVC LHCC LFMM LHKR LFEE UBBALFFF LSAG EDYY UKBV LECM ASU LECM LTAA ENOR
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 is available for industrialisation.

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.

IMPROVING CONFLICT ALERT FOR CONTROLLERS
Enhanced short-term conflict alert (STCA)
for terminal manoeuvring areas (TMAs)
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.

The solution is available for industrialisation.
FINE-TUNING COLLISION ALERTS

Enhanced airborne collision avoidance system (ACAS)

Existing airborne collision avoidance systems (ACAS) triggers resolution advisories when a collision risk is predicted. False 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 traffic 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 on close encounter, where there is an actual risk of mid-air collision, and an air traffic management encounter, 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 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 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.

The solution can bring significant operational benefits. By automatically reducing the vertical rate at the approach to the selected flight level, false 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.
Optimised ATM network services
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 is extending 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 are looking 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 aim to identify the interoperability requirements between air traffic control, airspace users and the Network Manager.

Meanwhile, a series of shadow-mode exercises are evaluating 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 validating the integration of weather information into the network - including meteorological forecasts - to improve tactical demand capacity balancing measures.

This solution is in the pipeline for delivery. Validation exercises are testing the operational feasibility of decision making based on data exchange in real time. The solution will be deployed across Europe in accordance with the Pilot Common Project.
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 due to be deployed across Europe in accordance with the Pilot Common Project.
ADVANCED FLEXIBLE USE OF AIRSPACE
Variable profile military reserved areas and enhanced civil-military collaboration

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 are demonstrating 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 will help to refine the interoperability requirements so there is better exchange of data between the different parties. A series of shadow-mode trials are also taking place to validate the benefits of sharing and using aeronautical information for mission-planning purposes.

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 in the pipeline for delivery and is due to be deployed across Europe in accordance with the Pilot Common Project.

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

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

STATUS
PCP
BETTER TOOLS FOR COMPLEXITY RESOLUTION

Automated support for traffic complexity detection and resolution

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.

Real-time simulations are being carried out to test the automation tools in the en-route environment, and the extended arrival manager time horizon. Further real-time simulations are assessing 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 in the pipeline for delivery and is due to be deployed across Europe in accordance with the Pilot Common Project.
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 miles-in-trail separation, to prevent sector overload.

SESAR is developing 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 should be 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 opportunity to use business-to-business (B2B) system-wide information management (SWIM) in the future.

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 in the pipeline for delivery and is due to be deployed across Europe in accordance with the Pilot Common Project.
STAKEHOLDERS

OPTIMISED ATM NETWORK SERVICES

STATUS

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 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.

Live trials are testing the concept to validate its feasibility with input from all actors involved. The trials include 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 in the pipeline for delivery and is due to be deployed across Europe in accordance with the Pilot Common Project.

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

MOVING TO TIME-BASED OPERATIONS

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

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.

BENEFITS

SJU references: #18/Release 5

ANSP
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STATUS

PCP

Optimised ATM network services 73
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.

The solution is available for industrialisation.
AIRLINE INPUT IMPROVES DEPARTURE OUTPUT

User-driven prioritisation process (UDPP) departure

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.

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.
Enabling aviation infrastructure
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.

Real-time simulations are assessing the technical feasibility of flight data trajectory sharing between adjacent air traffic service units through the use of the flight object. The information is used for the coordination of tasks and controller assistance services between different ground control centres. Specifically, the exercises demonstrate 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. This solution represents a key enabler to support all solutions that require interface between different ground control centres (e.g., free route).

This solution is in the pipeline for delivery. The aim is to ensure the industry standards for the exchange of flight information through the flight object will be in place to support its planned deployment in accordance with the Pilot Common Project.
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).

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 resequencing rates which result from the poor accuracy of trajectory predictions.

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.

The solution is available for industrialisation.
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 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 solution is in the pipeline for delivery. The extended flight plan is due to be deployed in Europe in accordance with the Pilot Common Project.
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 are assessing 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 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 in the pipeline for delivery.
STAYING AHEAD OF THE WEATHER

Meteorological information exchange

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 is developing 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 4DWeatherCube 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 in the pipeline for delivery. MET information exchange will be deployed as part of initial SWIM, in accordance with the Pilot Common Project.
LEARNING TO SWIM
Initial system-wide information management (SWIM) technology solution

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.

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 as follows:

- Aeronautical information reference model (AIM) 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.

This solution is the pipeline for delivery and is due to be deployed in Europe, in accordance with the Pilot Common Project. The first SWIM-enabled solution was introduced in 2014 to support the exchange of data between neighbouring airspace sectors.
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.

This solution is in the pipeline for delivery. Further work is expected to address the operational use by controllers.
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%.

This solution is in the pipeline for delivery.

**BENEFITS**

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

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

**In addition to changes required for ADS-B-in capability, improved hybrid surveillance would also require a TCAS II unit software update**
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 in the pipeline for delivery. Implementation will be subject to the demonstration of a viable business case.
A NEW GENERATION OF SATELLITE-BASED DATALINK COMMUNICATIONS

Air traffic services (ATS) datalink using Iris Precursor

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 in the pipeline for delivery. The transition roadmap from Iris Precursor to the future communication infrastructure is currently being addressed by SESAR 2020 - the next wave of research and innovation activities by the SESAR JU - as well as by the European Space Agency (ESA) and Inmarsat (Iris Service Evolution).
Lightening the Load
Flexible Communication Avionics

Today, civil aircraft are typically fitted with several radios. This is standalone equipment, which is not only costly but also adds to the weight and the energy consumption of the aircraft. At the same time, new technologies are expected to be implemented on board to meet the communication capacity and performance requirements of air traffic management in the future.

SESAR’s flexible communication avionics aims to overcome this equipment challenge with the introduction of multi-purpose communications equipment capable of fulfilling conventional radio transceiver functions using generic computing platforms and software. The solution has the potential to reduce the cost, weight, size, and power penalties of multiple radio systems on board aircraft, and to provide flexibility for adding, removing, replacing, or upgrading these systems. In doing so, the solution facilitates the transition from current to future technologies and is a key enabler to realising efficiently multi-link operations.

Since not all aircraft radios are used simultaneously in all airspaces, the solution brings the opportunity to build new dynamically reconfigurable radio systems to operate a specific radio link only when required. Such flexibility can allow a further reduction in the number of separate hardware components carried on board and can also improve availability of the aircraft communication functions and aircraft interactions with the ground.

The feasibility of the solution has been validated through the development of two prototypes and laboratory testing, as well as complementary assessments on the benefits and challenges, for instance, related to security and certification.

This solution is in the pipeline for delivery.
IMPRESSIVE SURVEILLANCE SECURITY AND INTEGRITY
ADS-B surveillance of aircraft in flight and on the surface

Automatic dependent surveillance-broadcast (ADS-B) is a technique which allows the tracking of aircraft in flight and on the surface. Enhancements of 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.

The SESAR solution consists of the ADS-B ground station and the surveillance data processing and distribution (SDPD) functionality. The solution also offers 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 and derives synergies.

This solution is in the pipeline for delivery.
The SESAR JU will build on the solutions included in this catalogue in SESAR 2020, the next wave of air traffic management research and innovation for Europe. 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 to contribute to the SES High Level Goals.

In SESAR 2020 the focus will be on 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 upon optimising network services through increased dynamic data sharing between airlines and air traffic control. New technical and operational solutions as well as other important evolving challenges, such as the integration of remotely piloted air systems into controlled airspace and cyber security, will also be covered.

The combined resources of SESAR members and industry partners will continue to bring benefits in key performance areas of safety, operational efficiency, security, capacity and the environment, both in terms of local, fast-tracking solutions to individual stakeholder challenges or more strategic long-term infrastructure improvements.
## Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ACAS</td>
<td>Airborne collision avoidance system</td>
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<tr>
<td>A-CDM</td>
<td>Airport collaborative decision making</td>
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<tr>
<td>ADDEP</td>
<td>Airport departure data entry panel</td>
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<tr>
<td>ADS-B</td>
<td>Automatic dependent surveillance – broadcast</td>
</tr>
<tr>
<td>AEEC</td>
<td>Airlines Electronic Engineering Committee</td>
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<tr>
<td>AFIS</td>
<td>Aerodrome flight information services</td>
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<tr>
<td>AFUA</td>
<td>Advanced flexible use of airspace</td>
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<tr>
<td>AIRM</td>
<td>Aeronautical information reference model</td>
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<tr>
<td>ANSP</td>
<td>Airspace navigation service provider</td>
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<tr>
<td>AO</td>
<td>Airport operators</td>
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<tr>
<td>AOC</td>
<td>Airline operational control</td>
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<tr>
<td>AOP</td>
<td>Airport operations plan</td>
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<tr>
<td>AMAN</td>
<td>Arrival manager</td>
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<tr>
<td>APOC</td>
<td>Airport operations centre</td>
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<tr>
<td>ASAS</td>
<td>Airborne separation assistance system</td>
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<tr>
<td>A-SMGCS</td>
<td>Advanced surface movement guidance and control systems</td>
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<tr>
<td>ATC</td>
<td>Air traffic control</td>
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<tr>
<td>ATFCM</td>
<td>Advanced short-term air traffic flow capacity management</td>
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<tr>
<td>ATM</td>
<td>Air traffic management</td>
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<tr>
<td>AU</td>
<td>Airspace user</td>
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<tr>
<td>CAR</td>
<td>Complexity assessment and resolution</td>
</tr>
<tr>
<td>CBA</td>
<td>Cost-benefit analysis</td>
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<tr>
<td>CDA</td>
<td>Continuous descent approach</td>
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<tr>
<td>CDM</td>
<td>Collaborative decision making</td>
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<tr>
<td>CDO</td>
<td>Continuous descent operations</td>
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<tr>
<td>CNS</td>
<td>Communications, navigation and surveillance</td>
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<tr>
<td>CONOPS</td>
<td>Concept of Operations</td>
</tr>
<tr>
<td>COS</td>
<td>Conflict organiser and signaler</td>
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<tr>
<td>CPDLC</td>
<td>Controller-pilot datalink communications</td>
</tr>
<tr>
<td>CTA</td>
<td>Controlled time of arrival</td>
</tr>
<tr>
<td>CTOT</td>
<td>Calculated take-off times</td>
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<tr>
<td>DCB</td>
<td>Dynamic capacity balancing</td>
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<tr>
<td>DMAN</td>
<td>Departure manager</td>
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<tr>
<td>D-TAXI</td>
<td>Datalink taxi</td>
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<tr>
<td>E-AMAN</td>
<td>Extended AMAN</td>
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<tr>
<td>EASA</td>
<td>European Aviation Safety Agency</td>
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<tr>
<td>EATMA</td>
<td>European ATM architecture</td>
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<tr>
<td>EFB</td>
<td>Electronic flight bag</td>
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<tr>
<td>EFPL</td>
<td>Extended flight plan</td>
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<tr>
<td>eFDP</td>
<td>Electronic flight data processing</td>
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<td>EGNS</td>
<td>European Geostationary Navigation Overlay Service</td>
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<td>ERM</td>
<td>Environment reference material</td>
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<td>ESA</td>
<td>European Space Agency</td>
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<td>EU</td>
<td>European Union</td>
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<tr>
<td>EOCVM</td>
<td>European operational concept validation methodology</td>
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<tr>
<td>FAB</td>
<td>Functional Airspace Block</td>
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<td>FABEC</td>
<td>Functional Airspace Block Europe Central</td>
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<tr>
<td>FASTI</td>
<td>First ATC support tools implementation</td>
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<tr>
<td>FCI</td>
<td>Future communication infrastructure</td>
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<tr>
<td>FF-ICE</td>
<td>Flight and flow information for the collaborative environment concept</td>
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<tr>
<td>FRA</td>
<td>Free route airspace</td>
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<td>FRT</td>
<td>Fixed radius transition</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>FMP</td>
<td>Flow management position</td>
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<tr>
<td>FRT</td>
<td>Fixed radius transition</td>
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<tr>
<td>GBAS</td>
<td>Ground-based augmentation system</td>
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<tr>
<td>GLS</td>
<td>GBAS landing system</td>
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<tr>
<td>GNSS</td>
<td>Global navigation satellite system</td>
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<tr>
<td>GPS</td>
<td>Global positioning system</td>
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<tr>
<td>i4D</td>
<td>Initial four dimensional trajectory management</td>
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<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<tr>
<td>ICT</td>
<td>Information and communications technology</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers, Inc.</td>
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<tr>
<td>ILS</td>
<td>Instrument landing system</td>
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<tr>
<td>ISRM</td>
<td>Information service reference model</td>
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<tr>
<td>JU</td>
<td>Joint Undertaking</td>
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<tr>
<td>LPV</td>
<td>Localiser performance with vertical guidance</td>
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<td>METSPs</td>
<td>Meteorological service providers</td>
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<tr>
<td>MLAT</td>
<td>Multi-lateralion</td>
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<tr>
<td>MONA</td>
<td>Monitoring aids</td>
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<td>MOPS</td>
<td>Minimum operational performance standards</td>
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<tr>
<td>MTCD</td>
<td>Medium-term conflict detection</td>
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<tr>
<td>NM</td>
<td>Nautical mile</td>
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<tr>
<td>NM</td>
<td>Network Manager</td>
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<td>NOP</td>
<td>Network operations plan</td>
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<tr>
<td>NOTAM</td>
<td>Notice to airmen</td>
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<tr>
<td>OLDI</td>
<td>On-line data interchange</td>
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<tr>
<td>PCP</td>
<td>Pilot Common Project</td>
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<tr>
<td>PBN</td>
<td>Performance-based navigation</td>
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<tr>
<td>P-RNAV</td>
<td>Precision area navigation</td>
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<tr>
<td>RA</td>
<td>Resolution advisory</td>
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<td>REL</td>
<td>Runway entrance lights</td>
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<tr>
<td>RF</td>
<td>Radius-to-fix</td>
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<td>RIL</td>
<td>Runway intersection lights</td>
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<td>RNP</td>
<td>Required navigation performance</td>
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<td>RTA</td>
<td>Required time of arrival</td>
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<td>RTS</td>
<td>Remote tower services</td>
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<td>RWSL</td>
<td>Runway status light</td>
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<td>SATCOM</td>
<td>Satellite communications</td>
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<td>SDPD</td>
<td>Surveillance data processing and distribution</td>
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<td>SecRAM</td>
<td>SESAR ATM security risk assessment methodology</td>
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<td>SES</td>
<td>Single European Sky</td>
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<tr>
<td>SESAR</td>
<td>Single European Sky ATM Research</td>
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<tr>
<td>SIGMET</td>
<td>Significant meteorological information</td>
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<td>SMGCS</td>
<td>Surface movement guidance and control system</td>
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<td>SMR</td>
<td>Surface movement radar</td>
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<td>SRM</td>
<td>Safety reference material</td>
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<td>STAM</td>
<td>Short-term ATFM measures</td>
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<td>STCA</td>
<td>Short-term conflict alert</td>
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<td>SWIM</td>
<td>System-wide information management</td>
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<td>SWIM TI</td>
<td>SWIM technical infrastructure</td>
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<tr>
<td>TBS</td>
<td>Time-based separation</td>
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<td>TCAS</td>
<td>Traffic alert and collision avoidance system</td>
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<td>THL</td>
<td>Take-off hold lights</td>
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<tr>
<td>TMA</td>
<td>Terminal manoeuvring area</td>
</tr>
<tr>
<td>TOBT</td>
<td>Target off-block time</td>
</tr>
<tr>
<td>TP</td>
<td>Trajectory predictors</td>
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<tr>
<td>TSAT</td>
<td>Target start-up approval time</td>
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<tr>
<td>TTL</td>
<td>Time-to-lose</td>
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<tr>
<td>TTTOT</td>
<td>Target take-off time</td>
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<tr>
<td>UDPPP</td>
<td>User-driven prioritisation process</td>
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<tr>
<td>VPA</td>
<td>Variable profile areas</td>
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<td>V-PAT</td>
<td>Vertical flight path analysis</td>
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<tr>
<td>WAM</td>
<td>Wide area multi-lateralion</td>
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<tr>
<td>WeP</td>
<td>What-else probing</td>
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<tr>
<td>WiMAX</td>
<td>Aviation airport surface datalink system</td>
</tr>
</tbody>
</table>
Notes