SESAR

THE ROADMAP FOR DELIVERING HIGH PERFORMING AVIATION FOR EUROPE

European ATM Master Plan

Executive View

Edition 2015

EUROPEAN UNION

EUROCONTROL

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Executive Summary

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What is the European ATM Master Plan?

Within the framework of the Single European Sky (SES), the European Air Traffic Management Master Plan (hereafter referred to as 'the Master Plan') is the main planning tool for defining ATM modernisation priorities and ensuring that the SESAR (Single European Sky ATM Research) Target Concept becomes a reality. The Master Plan is an evolving roadmap and the result of strong collaboration between all ATM stakeholders. As the technological pillar of the SES initiative, SESAR contributes to achieving the SES High-Level Goals and supports the SES regulatory framework.

The Master Plan details not only a high-level view of what is needed to be done in order to deliver a high-performing ATM system, but also explains why and by when. It therefore sets the framework for the development activities performed by the SESAR Joint Undertaking (SJU) in the perspective also of the deployment activities to be performed by all operational stakeholders under the coordination of the SESAR Deployment Manager and in accordance with the Deployment Programme to ensure overall consistency and alignment.

Why act now?

ATM is a critical element in the European air transport value chain and key to connecting regions and making Europe a global hub for mobility and prosperity. To ensure the sustainability and competitiveness of aviation, Europe needs to have a clear vision on how to deliver a high-performing ATM system.

Since the 2012 edition of the Master Plan, several significant developments have taken place, such as the availability of the first SESAR Solutions, the start of deployment activities and the significant change to the long term traffic forecast. ATM modernisation therefore needs to reflect a greater focus on increased efficiency and effectiveness while sustaining or even improving the levels of safety and security. At the same time, it must also recognise the need to provide solutions to address critical capacity bottlenecks.

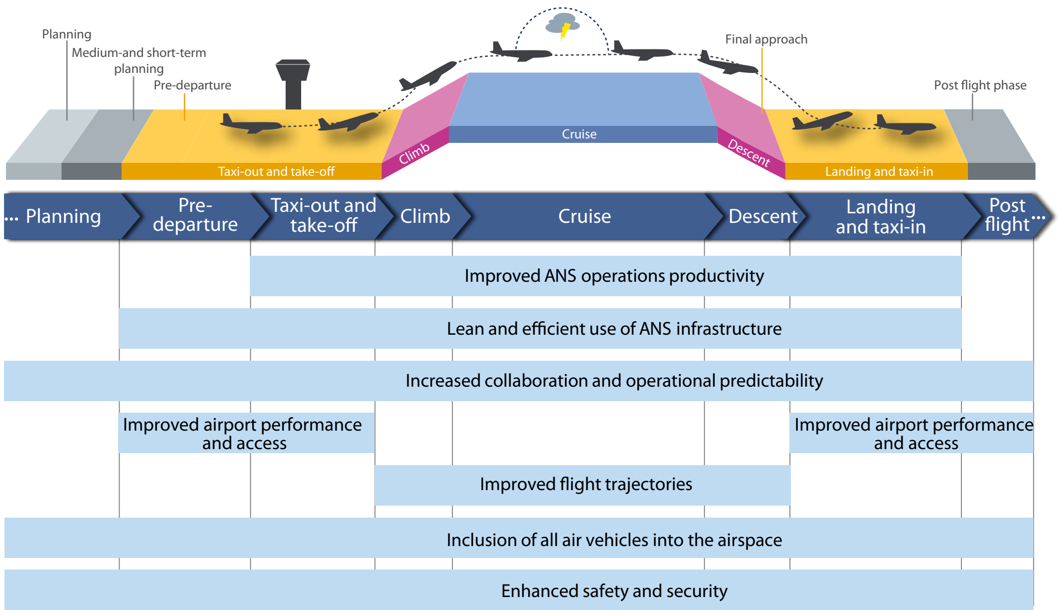
What's new in the 2015 edition of the Master Plan?

Mindful of these developments, this edition of the Master Plan:

- introduces a vision for the future European ATM system;
- presents the first wave of SESAR deployment, such as the Pilot Common Project (PCP) ([1]), and details the Key Features of R & D activities (SESAR 2020);
- provides new deployment scenarios for elements that are sufficiently mature to be brought into the deployment pipeline;
- makes explicit reference to remotely-piloted aircraft systems (RPAS) and rotorcraft as airspace users, as well as to cybersecurity elements within ATM;
- incorporates the results of a more comprehensive military involvement;
- reflects synergies and consistencies with the Deployment Programme and the Network Strategy Plan.

([1]) Commission Implementing Regulation EU No 409/2013 specified the requirements for common projects. Common projects aim to deploy in a timely, coordinated and synchronised way ATM functionalities that are mature for implementation and that contribute to the Essential Operational Changes identified in the European ATM Master Plan (2012 edition). The first of these common projects is the Pilot Common Project (PCP).

Create benefits for EU citizens



What is the vision of the 2015 Master Plan?

Building on the 2012 edition of the Master Plan, this edition outlines the vision to achieve 'high-performing aviation for Europe' by 2035. The vision reflects the goals captured in the SES II initiative, which calls for 'more sustainable and better performing aviation' (²) and Flightpath 2050 — Europe's Vision for Aviation (³), which states that in 2050, 'The European aviation community leads the world in sustainable aviation products and services, meeting the needs of EU citizens and society'.

The vision builds on the notion of 'trajectory-based operations' and relies on the provision of air navigation services (ANS) in support of the execution of the business or mission trajectory — meaning that aircraft can fly their preferred trajectories without being constrained by airspace configurations. This vision is enabled by a progressive increase of the level of automation support, the implementation of virtualisation technologies as well as the use of standardised and interoperable systems. The system infrastructure will gradually evolve with digitalisation technology, allowing air navigation service providers (ANSPs), irrespective of national borders, to plug in their operations where needed, supported by a range of information services. Airports will be fully integrated into the ATM network level, which will facilitate and optimise airspace user operations. Going beyond 2035 towards 2050, performance-based operations will be implemented across Europe, with multiple options envisaged, such as seamless coordination between ANSPs or full end-to-end ANS provided at network level.

Furthermore, it is widely recognised that to increase performance, ATM modernisation should look at the flight as a whole, within a flow and network context, rather than segmented portions of its trajectory, as is the case today. With this in mind, the vision will be realised across the entire ATM system, offering improvements at every stage of the flight.

Reaching the performance ambition will also require a change in the way that solutions are deployed, as well as possible evolutions in the way services are provided. Through a four-phase approach, this change would see the high-level architecture gradually moving from locally specific architecture to a more interoperable, common and flexible service provision infrastructure at regional or network level (see Chapter 2).

(²) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions on SES II, COM(2008) 389/2, 25 June 2008.

(³) Report of the High-Level Group on Aviation Research, 2011, EUR 098 EN.

SESAR's performance ambition

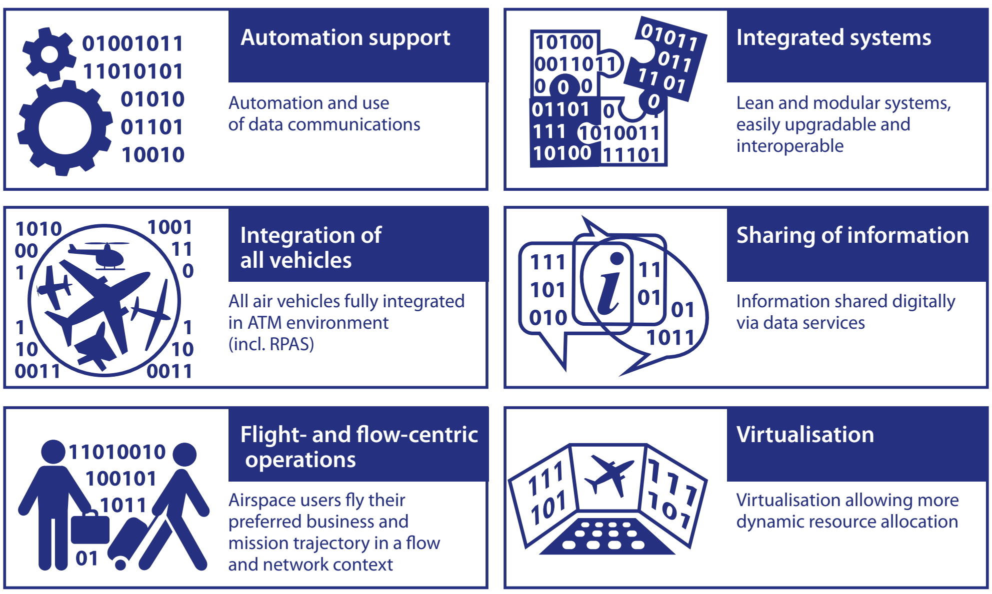
What is the ATM performance ambition for Europe?

The performance ambition supported by SESAR is aspirational and refers to the performance capability that may be achieved if SESAR Solutions are made available through R & D activities, deployed in a timely and, when needed, synchronised way and used to their full potential. While acknowledging that the performance gains at local level will also depend on local conditions, it shows that significant performance gains can be achieved in Europe in a number of key areas, namely the environment, capacity, cost efficiency, operational efficiency, in addition to safety and security. The ambitions described are compared to the situation in 2012 and rely on the optimal development and deployment of a series of operational changes through SESAR Solutions (see Chapter 3).

What is needed to achieve this performance ambition?

The technical evolution of the future system is now closely connected to these performance ambition levels. In order to deliver, SESAR will enable a step change in system capabilities

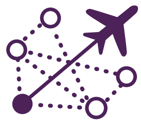
What is needed to achieve the performance ambition?



by 2035 with higher levels of automation, digitalisation and virtualisation.

The Master Plan identifies the related changes and groups them according to whether they are already in place, in the pipeline towards deployment, or planned as part of future R & D activities (see Chapter 4).

These changes are categorised according to four areas of ATM (Key Features):


Optimised ATM network services


High-performing airport operations


Advanced air traffic services


Enabling aviation infrastructure

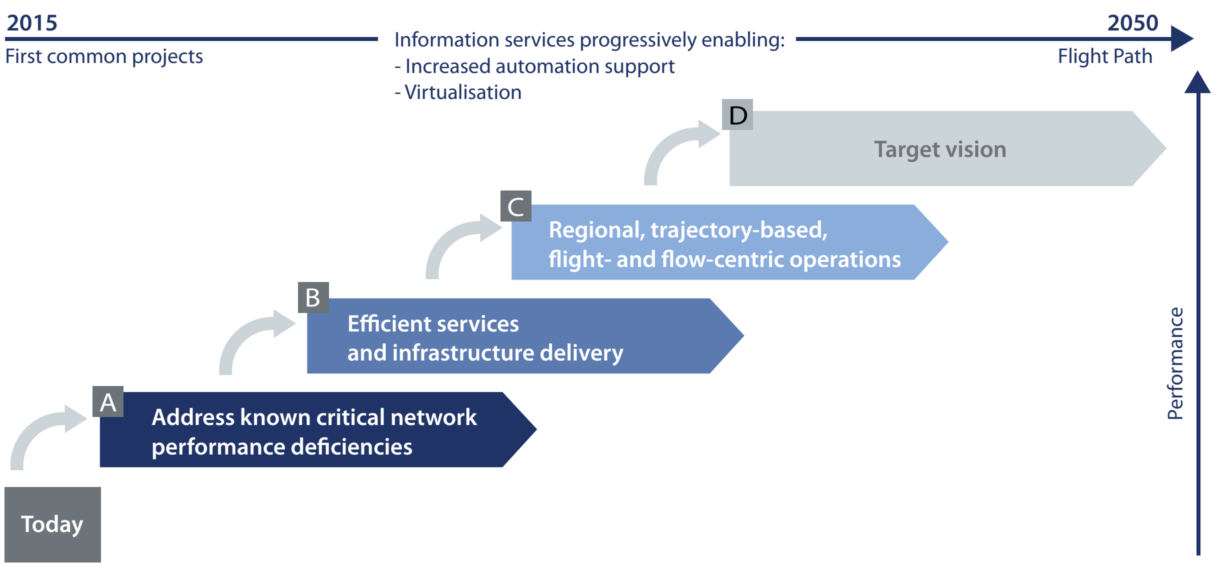
Further operational changes relating to RPAS and cybersecurity are also featured in the Master Plan. Key to success is the ATM workforce, which the Plan underlines as an integral part of the overall ATM system, and as the most critical source of its performance, safety and resilience. As in past and present operations, ATM performance will remain the result of a well-designed interaction between human, procedural, technological, environmental and organisational aspects.

What is the timeline for deployment?

The operational changes are enabled through improvements to technical systems, procedures, human factors and institutional changes supported by standardisation and regulation.

The Master Plan includes roadmaps of the identified changes, ensuring that their deployment is planned in a performance-driven and synchronised way (e.g. between ground and air deployments) to maximise the benefits gained. The Master Plan also gives targeted dates for deployment; however, these are subject to further considerations after validation and proper identification of supporting business cases.

Four-phase approach to improvements



Delivering expected benefits

Direct and quantifiable benefits for European ATM and aviation	Benefits for EU economy and society
- **ANS productivity:** reduced en-route and TMA costs per flight - **Operational efficiency for airspace users:** reduced fuel burn and flight time - **Capacity:** reduced delays, increased network throughput and throughput at congested airports - **Environment:** reduced CO_2 emissions - **Safety and security:** high standards	- Industrial leadership in ATM and aviation at the forefront of innovation - A more competitive EU aviation industry in the global aviation landscape - Increased mobility with a lower environmental impact - Significant contribution to EU GDP and job creation - High standards in terms of safety, security and social standards

What are the expected costs and benefits?

The realisation of the vision will not only bring significant direct and quantifiable performance gains to ATM and aviation, but it will also mean benefits for the EU economy and society in general, as described.

In terms of cost savings, the Master Plan estimates important improvements in several areas, depending on how SESAR is deployed. Two options are put forward: on the one hand an optimised deployment scenario with greater integration of the ATM infrastructure, and on the other hand a local deployment scenario.

It is estimated that cost savings and the value of all performance benefits would amount to annual recurring benefits ranging potentially from EUR 8 billion to EUR 15 billion per year in 2035, compared to a scenario where SESAR would not be deployed. These savings imply higher levels of coordination on how and where to invest, as well as the early application of standardisation and harmonisation of procedures. More critically, these savings also rely on the deployment of infrastructure with a long-term horizon which is optimised at network level, amounting to a total investment in the range of EUR 18 billion to EUR 26 billion in the period up until 2035 (see Chapter 6).

Why is the Master Plan important for global interoperability?

Aviation is a global industry and interoperability together with global harmonisation are key for its safe and sustained growth. The EU-US Memorandum of Cooperation (MoC) provides the framework for SESAR and FAA's NextGen coordinated approach in particular with regards to the International Civil Aviation Organisation's (ICAO) harmonisation efforts. This latest update of the Master Plan is timely as it will serve to contribute to the update of the ICAO's Global Air Navigation Plan (GANP) and the Aviation System Block Upgrades (ASBUs) in 2016.

The Master Plan: a shared and maintained strategy for the evolution of European ATM

The Master Plan is a regularly updated plan (every 2-3 years) which involves all stakeholders. It represents the strategy for the performance-driven evolution of the European ATM system for institutional as well as industrial players.

The Master Plan's successful implementation is a key enabler for high-performing aviation in Europe, providing increased connectivity, supporting sustainable economic growth and promoting European industrial leadership at a global level.

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1 Introduction

1 Introduction

The Single European Sky (SES) initiative aims to achieve 'more sustainable and high-performing aviation' ([4]) in Europe. Aviation is an important driver of economic growth, jobs and trade, with a major impact on the life and mobility of EU citizens.

A performance-driven and technologically-enhanced air traffic management (ATM) system is recognised as a critical element for achieving greater connectivity and ensuring the sustainability of the aviation sector in Europe. That is why in 2004, the SESAR (Single European Sky ATM Research) project was set up to modernise and harmonise ATM systems through the definition, development and deployment of innovative technological and operational solutions (SESAR Solutions).

([4]) Communication from the European Commission to the European Parliament, European Council, the European Economic and Social Committee and the Committee of Regions (COM(2008) 389/2 of 25 June 2008) on Single European Sky II.

1.1 Single European Sky High-Level Goals — overall performance ambition

SESAR is the technological pillar of the SES ([5]), an EU-wide framework whose aspirational High-Level Goals stated in 2005 are 'to enable a threefold increase in capacity which will also reduce delays both on the ground and in the air; to improve safety by a factor of 10; to enable a 10 % reduction in the effects flights have on the environment; and to provide ATM services to airspace users at a cost of at least 50 % less ([6]). SESAR contributes to these High-Level Goals by harnessing the expertise and resources of the entire ATM community, from the Network Manager and civil and military air navigation service providers (ANSPs), to airports and military aerodromes opened to civil air traffic, civil and military ([7]) airspace users, staff associations, academia and research centres.

([5]) Regulation (EC) No 549/2004 of the European Parliament and of the Council of 10 March 2004 laying down the framework for the creation of the Single European Sky ('Framework Regulation') — Statement by the Member States on military issues related to the Single European Sky [See amending act(s)].

([6]) Communication from the Commission to the Council and to the European Parliament COM(2008) 750 final of 14.11.2008

([7]) Military national and collective airspace users. Civil airspace users include scheduled aviation, business aviation and general aviation.

1.2 ATM in a changing landscape

Long-term forecasts with horizons of up to 20 years are clearly prone to changes due to economic, political and social conditions, as indicated in the 2013 edition of the EUROCONTROL study, 'Challenges of Growth' ([8]). The study estimates (see Figure 1) that there will be between 3.4 million and 5.2 million fewer flights in 2030 compared to the 2010 Statistics and Forecasts (STATFOR) long-term forecasts upon which the 2nd edition of the Master Plan (2012) was built. The reasons offered for the change in forecast are many, but most notable among them are a series of interrelated factors such as high volatility in air traffic demand since 2008, the economic downturn, a sharp reduction in airport expansion plans and the growth of Middle East hubs.

According to the 'most-likely' scenario of the STATFOR forecast ([9]), there will be 14.4 million flights in Europe in 2035, 1.5 times the level of 2012 (see Figure 1). While growth will average 1.8 % annually (or around half the rate observed in the 40 years preceding 2008), it will be faster in the early years, stronger in Eastern Europe and faster for traffic to and from Europe than for intra-European flights. As of 2025, traffic growth will slow down as markets mature, economic growth decelerates and as capacity limits at airports increasingly become an issue.

The major challenge will be how to improve ATM cost efficiency in a slow growing market. There is also a need to act insofar as air transport in Europe faces a number of challenges that may jeopardise its sustainability, safe growth and profitability. The SESAR vision (hereafter referred to as 'vision') to address these challenges is set out in Chapter 2.

([8]) Challenges of Growth 2013 Summary report — 2013.
([9]) Source: EUROCONTROL STATFOR

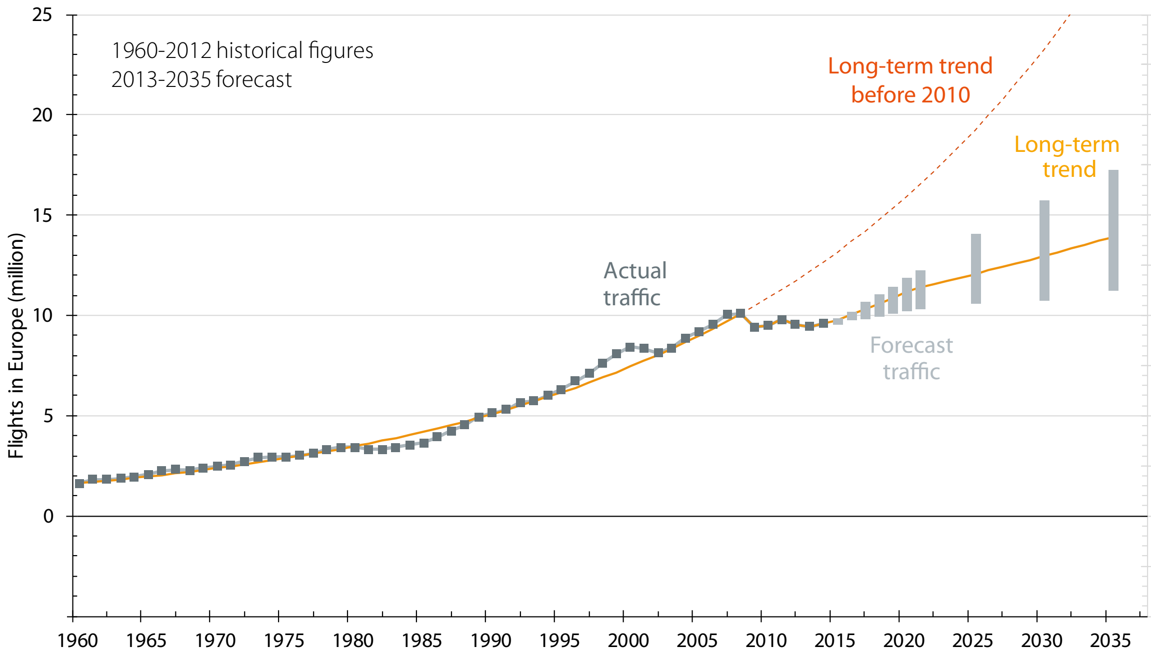
SESAR: the building blocks

2004 — Launch of the SESAR Definition Phase as part of the SES initiative.

2007 — Establishment of the SESAR Joint Undertaking (SJU) as a public private partnership to pool the knowledge and resources of the entire ATM community in order to define, research, develop and validate SESAR Solutions.

2014 — Establishment of the SESAR Deployment Manager (SDM) as a partnership between airlines, airports and air navigation service providers to coordinate the implementation of the EU's Pilot Common Project.

Figure 1 **Instrument flight rules (IFR) traffic in Europe**



1.3 What is the European ATM Master Plan?

The European ATM Master Plan (hereafter referred to as 'the Master Plan') is the main planning tool for setting the ATM priorities and ensuring that the SESAR Target Concept becomes a reality. The Master Plan is an evolving roadmap built in collaboration with, and for the benefit of, all stakeholders. This aspirational document outlines the vision and performance ambitions for the future ATM system within a timeframe up to 2035 with an outlook towards 2050, and then prioritises the R & D activities and solutions needed to achieve these. By connecting SESAR R & D with deployment, the Master Plan provides the basis for the European Commission to define common projects, which are then deployed by the SESAR Deployment Manager. The Master Plan also provides stakeholders with a Business View of what deployment will mean in terms of return on investment. Being part of a European endeavour, like the Master Plan, means that the choices being made are going to be European choices extending into the worldwide context, thereby reducing technological risk and increasing predictability for the industry's development and deployment activities.

The first edition of the Master Plan was derived from the 'SESAR Master Plan' issued in May 2008 as one of the six main deliverables from the definition phase of SESAR, as agreed by all major European aviation stakeholders. The plan was endorsed by the Transport Council of the European Union on 30 March 2009. Although not legally binding, such an endorsement represented a clear political commitment to the SESAR project and an acknowledgement of the importance of the Master Plan. The plan is maintained by the SESAR Joint Undertaking (SJU) ([10]) and forms the foundation of the first SESAR R & D work programme (SESAR 1).

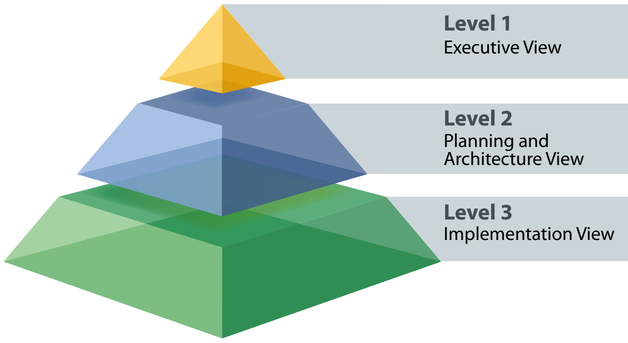
The 2nd edition of the Master Plan, published in October 2012, was a significant update and outlined Essential Operational Changes and technology changes needed to contribute to achieving the SES strategic performance objectives. These updates have transformed the Master Plan into a key tool for SESAR deployment and provided the basis for timely, coordinated and efficient deployment. The Master Plan also represented a key input to the 12th Air Navigation Conference (November 2012) and the ICAO Global Air Navigation Plan (GANP).

The three levels of the Master Plan

The content of the Master Plan is structured in three levels, as shown in Figure 2, to allow stakeholders to access the information at the level of detail that is most relevant to their area of interest.

([10]) The Master Plan is under the sole ownership of the SJU in compliance with the EU Council Regulation.

Figure 2 **Three levels of the European ATM Master Plan**



This document represents the Executive View of the Master Plan (Level 1). The Master Plan comprises an integrated set of information, with Level 1 constituting the synthesis consisting of:

- Executive Summary;
- The SESAR Vision;
- Performance View;
- Operational View;
- Deployment View;
- Business View;
- Risk Management.

The intended readership for Level 1 is executive-level stakeholders. Levels 2 and 3 of the Master Plan provide more detail on the operational changes and related elements and therefore the target audience is expert-level stakeholders.

Level 2 (Planning and Architecture View) is available through the European ATM portal (www.atmmasterplan.eu), which provides the detailed planning and architecture information supporting Level 1.

Level 3 (Implementation View) comprises the European Single Sky ImPlementation (ESSIP) Plan (and Report), which is a set of commonly-agreed implementation actions. These actions, including those resulting from the other SES plans such as the SESAR Deployment Programme, help to achieve the performance targets ([11]) in the areas of safety, environment, capacity and cost efficiency. In addition, Level 3 of the Master Plan provides stakeholders with a basis for short-term common implementation planning.

The European ATM portal provides information at all three levels in an interactive way. From the visualisation of information at Level 1, a 'drill-down' capability provides access to related information on the Planning, Architecture and Implementation Views (Levels 2 and 3 respectively).

([11]) Commission implementing Regulation (EU) No 390/2013

1.4 2015 edition of the Master Plan: significant updates

The Master Plan is a maintained plan that must take into account the changing ATM landscape and needs of stakeholders. This has to be done without losing sight of the bigger picture, namely the need to increase the performance of aviation and ATM in Europe. The 2015 edition represents an evolution of the 2nd edition (2012) with significant updates. Specifically, this latest edition:

- outlines the performance ambition, which is supported by the SESAR project and which reflects the evolution in European aviation and air transport, as well as stakeholders' needs;
- introduces a vision for the future European ATM system, including Common Support Services and cybersecurity;
- introduces new deployment scenarios, which link operational changes and operating environments where benefits can be delivered in specified timescales;
- reflects the first wave of SESAR deployment, namely the Pilot Common Project (PCP) ([12]), identifies the new Essential Operational Changes and details the SESAR 2020 Key Features and R & D activities;
- explicitly introduces remotely-piloted aircraft systems (RPAS) and rotorcraft as airspace users;
- incorporates the results of more comprehensive military involvement through the European Defence Agency (EDA), which together with the North Atlantic Treaty Organization (NATO) and EUROCONTROL, jointly developed the material needed;
- further strengthens synergies and consistencies with the Network Strategy Plan and the SESAR Deployment Programme.

These updates are considered in the context of a number of key developments in the European ATM landscape, which are described hereafter.

([12]) The Commission Implementing Regulation EU No 409/2013 specified the requirements for common projects. Common projects aim to deploy in a timely, coordinated and synchronised way ATM functionalities that are mature for implementation and that contribute to the Essential Operational Changes identified in the 2nd edition European ATM Master Plan. The first of these common projects is the Pilot Common Project (PCP).

1.4.1 SESAR 1 and SESAR 2020

Since 2012, significant progress has been made on completing the R & D activities of the first SJU work programme (SESAR 1), leading to the delivery of SESAR Solutions, many of which are in the process of early implementation or are part of the PCP (see Success Stories). In 2014, in recognition of the need for sustained R & D investment, the mandate of the SJU was extended ([13]) and SESAR 2020 was launched. This latest programme addresses further several key areas of ATM, as well as new challenges, changing markets and the need for continuous and coordinated investment.

SUCCESS STORIES

Thanks to the roadmap provided by the Master Plan and the work undertaken in SESAR, a number of 'success stories' can be told about progress towards a more high-performing ATM system in Europe. These stories appear in boxes with a special stamp throughout this publication.

([13]) Council Regulation (EU) No 721/2014 of 16 June 2014, amending Regulation (EC) No 219/2007 on the establishment of a Joint Undertaking to develop the new generation European air traffic management system (SESAR) as regards the extension of the Joint Undertaking until 2024.

1.4.2 SESAR deployment

In the 2012 edition, the Master Plan already contained plans for future deployment, underlining the need to assess and select for deployment emerging solutions based on measurable performance gains not just locally but across the European network. Since then, Europe-wide deployment has been launched with the establishment in 2013 of the SESAR deployment framework under Regulation (EU) No 409/2013, followed by the adoption in 2014 of the PCP and, finally, the establishment of the SESAR Deployment Manager (SDM) to implement the PCP. The PCP aims to ensure that the solutions derived from the Master Plan are deployed in a timely, coordinated and synchronised manner to bring important performance and cost benefits for Europe's aviation and air transport sectors.

1.4.3 Increased synergies and collaboration

Military

The future ATM system concerns the entire ATM community. Although the military pursue different objectives, much of the time they operate in a mixed civil-military environment and contribute directly or indirectly to the aviation value chain. With this in mind, the preparation of this latest edition of the Master Plan saw increased participation and involvement by military stakeholders, through the EDA, to ensure

that the Master Plan answers the performance and business needs of this important stakeholder community.

Deployment Programme

The Master Plan addresses the high-level operational and technological evolution of the ATM system, based on performance ambitions and deployment scenarios. The Deployment Programme comprises a number of implementing projects, coordinated by the SDM, which contribute to the achievement of the Essential Operational Changes identified in the Master Plan.

Pushing the boundaries of ATM knowledge

As a global leader in ATM R & D, SESAR seeks to push the boundaries of our knowledge and understanding of what is possible in the future ATM system. At the heart of this endeavour are the 40 exploratory research projects, 20 PhD projects and 3 networks, which have led to the creation of a strong body of knowledge in SESAR 1 that is now serving the ATM community beyond the framework of SESAR. The transfer and further application of this knowledge has been made possible through the annual SESAR Innovation Days and the Young Scientist Award.

1.4.4 The link between the Master Plan and Network Strategy Plan

This latest edition of the Master Plan also reflects increased synergies with other stakeholders and their respective planning documents, such as the Network Strategy Plan.

The Network Strategy Plan is part of a wider change process driven by network operations and functions as stipulated in the Regulation (EU) No 677/2011 and its amendment No 970/2014. One of its main goals is to address ATM network performance as defined in the Performance Implementing Rule for the next reference period(s). It uses the technological developments as planned in the Master Plan and it complements them by providing the required additional operational objectives and solutions. Its time horizon is shorter than the Master Plan (9-12 years). The Network Strategy Plan and the Master Plan through their respective update cycles will continually maintain full consistency and alignment.

Cooperation agreement signed between the SESAR Joint Undertaking and the Deployment Manager

In 2015, the SJU and the SDM signed a Memorandum of Understanding, providing the basis upon which to build cooperation for the smooth and timely delivery and deployment of SESAR Solutions to the ATM community.

The agreement has several guiding principles, based on both organisations developing synergies where possible and endeavouring to be complementary to each other's activities. This involves the mutual and timely sharing of information for effective operations and communications, and harnessing existing cooperation mechanisms. Above all, a critical factor for success is the exchange of information to support the industrialisation phase, to ensure effective bridging between R & D and deployment and to facilitate interoperability.

1.5 The ATM innovation lifecycle

The Master Plan is ambitious in its scope, detailing not only a high-level view of what is needed in order to deliver a high-performing ATM system, but also all the activities which need to be undertaken so as to plan, implement and execute the Master Plan. These activities are integrated into the work programmes of the SJU and the SDM to ensure overall consistency and alignment. In doing so, this convergence between the Plan and the work programmes ensures that all phases of the ATM innovation lifecycle are addressed:

1.5.1 Research and development

The R & D phase begins with the definition of a concept, its scope, objectives and technical specifications and ends with a SESAR Solution. Validation means that the solution is technically and operationally feasible, has demonstrated performance improvements and an overall positive business case. It should also be possible in this phase to identify where and when the validated solution will be needed in order to deliver the required performance benefits. The successful transition through this phase is dependent on multiple factors, such as the involvement of the appropriate stakeholders and application of relevant governance structures, as well as planned industrialisation and deployment activities.

1.5.2 Industrialisation

This phase covers the development of operational systems, as well as standardisation-related activities and the development of procedures and systems (up until certification and based on the availability of regulatory material). This phase sees continued technical input from the SJU to reduce the gap between R & D and industrialisation. The duration of this phase is influenced by several factors, such as industrial cycles, decision-making processes and the capacity of the manufacturing industry to bring the solution to market. The length of this phase is also determined by the time it takes to finalise the development and validation of standards.

1.5.3 Deployment

This phase covers local deployments, as well as an optimised Europe-wide deployment which is supported through a regulatory framework with accompanying financial support. The first wave of Europe-wide deployment has started with the PCP and the Deployment Programme. The PCP sets out what should be implemented, where and by whom as well as the timeframes for implementation. The Deployment Programme provides a project-level breakdown of the PCP, including clear timelines and planning details. This means that the Deployment Programme has direct influence on the investment plans and investment decisions of each investor. Early planning is key for the stakeholders and the Deployment Programme is the tool to guide investment planning by each stakeholder. The aim of the Deployment Programme is to provide the best planning to optimise the investments in ATM and bring the best value for money.

1.6 Maintenance of the Master Plan

The Master Plan represents a snapshot in time and is updated on a regular basis, approximately 2-3 years, involving inputs from all stakeholders, and reflecting the results of the R & D programme and deployment activities.

2 The SESAR Vision

2 The SESAR Vision

The vision builds on the notion of trajectory-based operations and relies on the provision of air navigation services (ANS) in support of the execution of the business or mission trajectory — meaning that aircraft can fly their preferred trajectories without being constrained by airspace configurations. This vision is enabled by a progressive increase in the level of automation support, the implementation of virtualisation technologies and the use of standardised and interoperable systems. The system infrastructure will progressively evolve with digitalisation technology, allowing air navigation service providers (ANSPs), irrespective of national borders to plug in their operations where they are needed, supported by a range of information services. Airports will be fully integrated into the ATM network level, which will facilitate and optimise airspace user operations. Going beyond 2035 towards 2050, performance-based operations will be implemented across Europe, with multiple options envisaged, such as seamless collaboration between ANSPs or full end-to-end ANS provided at the network level.

Building on the 2nd edition of the Master Plan and the SESAR Target Concept, this version outlines the vision to achieve 'high-performing aviation for Europe' by 2035. The vision reflects the goals captured in the SES II initiative, which calls for 'more sustainable and better performing aviation' ([14]) and Flightpath 2050 — Europe's Vision for Aviation ([15]), which states that in 2050, 'The European aviation community leads the world in sustainable aviation products and services, meeting the needs of EU citizens and society', and broadens it to a pan-European network level. The vision also takes into account the work of SESAR 1 and SESAR 2020 to prioritise R & D activities and deliver solutions for deployment through common projects (CPs), as well as local implementation where appropriate. Furthermore, the vision reflects the evolving landscape of ATM, as well as emerging challenges and opportunities stemming from aviation and technology trends.

(14) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions on SES II, COM(2008) 389/2, 25 June 2008.

(15) Report of the High-Level Group on Aviation Research, 2011, EUR 098 EN.

2.1 Offering improvements across ATM

It is widely recognised that to increase performance, ATM modernisation should look at the flight as a whole and not in segmented portions, as is the case today. Mindful of this, the vision is realised across the entire ATM system, offering improvements at every stage of the flight (see Figure 3).

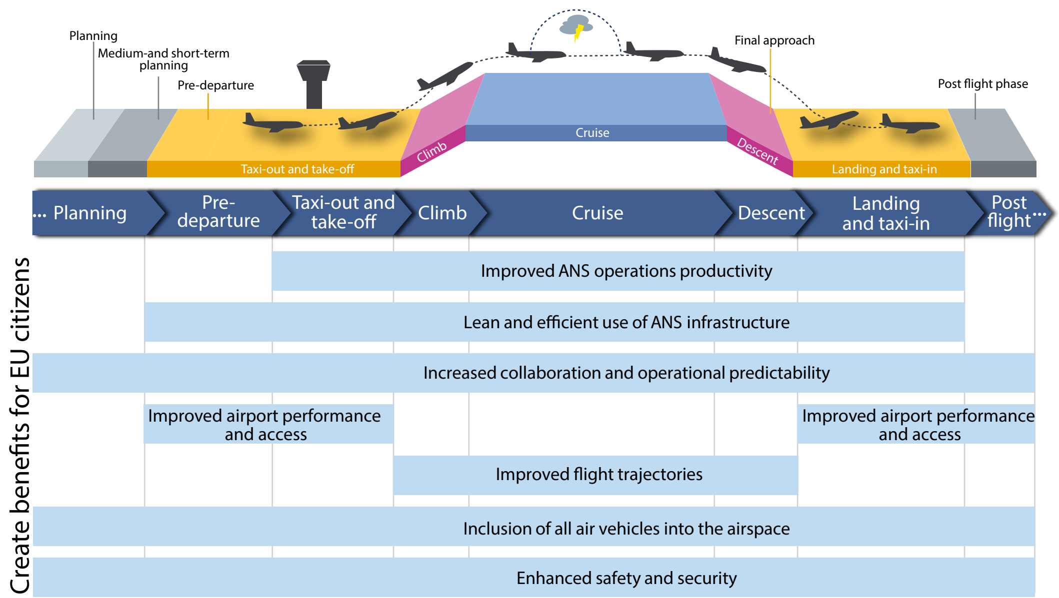
Improved ANS operations productivity: The improvement of ANS productivity is made possible in particular through the development and implementation of automation, reducing air traffic controllers' (ATCOs) need for intervention. This is achieved through improved planning, supported by planning and conflict resolution tools, as well as temporary delegation of separation to the aircraft. The automation of routine tasks and wide introduction of data communication will also allow ATCOs to concentrate on value-added tasks, thereby handling more traffic in a safer way and improving their productivity.

Lean and efficient use of ANS infrastructure: Through the standardisation and rationalisation of the infrastructure, including communications, navigation and surveillance (CNS), ANSPs will have leaner and more modular systems that are easier to upgrade and more interoperable with each other. The appropriate virtualisation of ANS will be achieved through the delivery of air traffic control (ATC) services irrespective of the location of the infrastructure. Virtual control centres and use of remote towers will allow a more efficient and flexible use of resources, substantially improving the cost efficiency of service provision and relieving congested airspace.

Increased collaboration and operational predictability: The exchange of trajectory information made possible through information management, supported by system-wide information management (SWIM), will enhance collaborative decision-making at a network level.

Improved airport performance and access: This will be achieved by implementing enhanced runway throughput capabilities, more accurate navigation and routing tools, and technical solutions allowing performance to be maintained in all weather conditions. The introduction of solutions such as remote tower services will enable operational coverage to be extended at low- and medium-traffic airports and will open up new markets (e.g. in airports serving isolated areas and communities, thus stimulating local economies).

Figure 3 **Improvements at every stage of the flight**



Improved flight trajectories: Trajectory-based operations (TBO) will see the sharing of the same information via SWIM and datalink communications between airborne and ground actors throughout the business-mission trajectory lifecycle. Thanks to TBO, flight- and flow-centric operations will be possible in a network context, such as sectorless operations. This will enable airspace users to fly their preferred trajectory — satisfying their business needs — and to perform continuous descent and climb, generating environmental benefits both in terms of emissions and noise. Airspace configuration will be dynamically adjusted in response to capacity and demand needs. Flight- and flow-centric operations in a network context will see the introduction of complexity tools to enable air traffic controllers to work on flows rather than individual flights. This will allow flexible and optimal use of controller resources, thereby generating step changes in productivity and cost efficiency.

Inclusion of all air vehicles into the airspace: Clear standards and low-cost system solutions which support interoperability will allow the integration of all airspace users (including airlines but also military, business, general aviation and rotorcraft users, as well as remotely-piloted aircraft systems (RPAS)) in an efficient and non-discriminatory manner, while also ensuring safety.

Enhanced safety: New concepts and technologies will enhance ATM safety in this new operational environment. The introduction of improved ground-based and airborne safety nets in all phases of flight, including on the airport surface, will maximise the future ATM system's contribution to aviation safety and minimise its contribution to the risk of accident.

Enhanced security: Security, in particular cybersecurity, will be addressed for the enabling infrastructure, including by securing data exchange and sharing within the context of SWIM.

SUCCESS STORY

World's first Initial four-dimension (i4D) flights

Initial four-dimensional trajectory management (i4D) makes use of the flight management system and communication capabilities of the aircraft and ground systems in order to share and integrate data, and optimise the aircraft trajectory in all four dimensions. This enables a more efficient and predictable handling of flights.

Thanks to i4D, controller workload can be optimised since conflicts between trajectories in the en-route phase can be resolved automatically. During the arrival planning, once they receive their allotted arrival time, aircraft can manage their arrivals with greater precision. This also allows aircraft to better manage their speed profile, which leads to fuel savings and lower emissions.

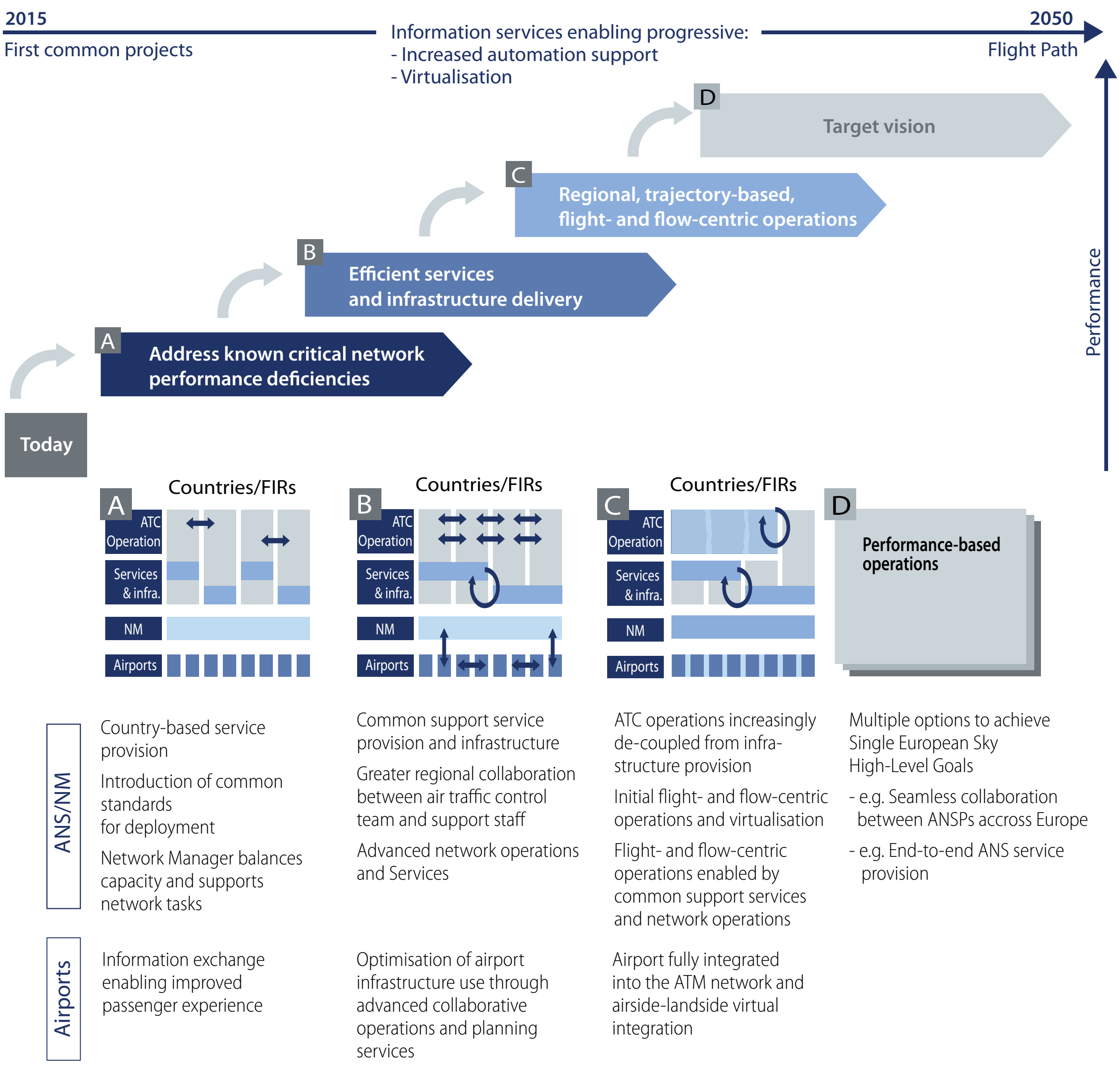
In 2012 and again in 2014, SESAR conducted the world's very first i4D flight trials, demonstrating the maturity and robustness of the application of this solution in real traffic conditions. The trials also confirmed the important efficiency and environmental gains, as well as increased flight predictability that can be achieved with i4D. Its synchronised deployment is planned in accordance with Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the Pilot Common Project (PCP).

2.2 Supporting change in ATM

The achievement of the aforementioned improvements with the maximum performance gains will require a change in the way solutions are deployed and services provided. Through a four-phase approach, this change would see the high-level architecture gradually moving from a country-specific architecture to a more interoperable, common and flexible service provision infrastructure (see Figure 4). It should be noted that these phases overlap in sequence rather than one phase following another.

These phases are described hereafter:

Figure 4 **Four-phase approach to improvements**



A. Address known critical network performance deficiencies

Although for the most part ANSPs are still vertically integrated into country-based infrastructures, this phase sees the gradual adoption of a service-oriented architecture (SOA) as the basis for SWIM. The move towards open architecture and standards, and common data models sees further actions undertaken to enhance cybersecurity (see Chapter 5, Section 5.5.4). This approach allows increased information-sharing and exchange between ATM stakeholders, including the Network Manager (NM), airlines and airports across national borders. This phase has already started with the delivery of mature solutions by SESAR 1 and the implementation of the PCP and will continue with the next common projects, the content and timeframe of which will be decided by the European Commission.

B. Efficient services and infrastructure delivery

The development of open standards for the ATM system also means that stakeholders will find commonalities in terms of their operations and service needs, allowing for the development and introduction of 'Common Support Services'. This enables the optimisation and rationalisation of ATM and airport operations' support services, enabling the move from physical to virtual infrastructures that are characterised by automation and digitalisation of information management. This phase is reliant on the delivery of a continued flow of solutions from the SESAR 2020 R & D activities and demonstrated evidence of the performance gains expected for Europe-wide and/or local deployment, where appropriate.

C. Regional, trajectory-based, flight- and flow-centric operations

By this phase, the ATM system has greater levels of automation and is using standardised and interoperable systems to enable trajectory-based and flight-centric operations within a network context — meaning that aircraft can fly their preferred trajectories without being constrained by airspace configurations. The implementation of these operations can be gradual; it may start at a regional level, or for some parts of the airspace only, or at some moments in time only. The development of further 'Common Support Services' results in a decoupling between the system infrastructure and air traffic control operations, allowing ANSPs irrespective of national borders to plug in their services where they are needed, providing end-to-end services. This phase also sees the full integration of airports into ATM at network level, which in turn facilitates airspace user operations, thereby reducing the impact of ATM on user costs. Again, this phase is reliant on the delivery of a continued flow of solutions from the SESAR 2020 R & D activities and demonstrated evidence of the performance gains expected for Europe-wide, regional and/or local deployment where appropriate.

Seamless and interoperable ATM

Europe has some of the busiest airspace in the world, managed by a network covering 11.5 million km² of airspace with 63 en-route centres. Today, when an aircraft leaves one national airspace and enters another, the adjacent centres use an online data interchange mechanism (OLDI) to share flight information. 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 up-to-date and consistent flight information between all actors managing an aircraft at all stages of its journey. Through extensive validation exercises, SESAR partners are showing the tangible efficiency gains that this solution offers. They are also ensuring that industry standards for the exchange of flight information through the flight object are in place to support the planned deployment as part of the PCP.

D. Target vision: performance-based operations

By this phase, the target vision has been reached in which the ATM system is characterised by a high degree of automation. In this context, multiple options can be envisaged, such as seamless collaboration between ANSPs across Europe and/or end-to-end ANS service provision. Going beyond 2035 towards 2050, continued R & D activities focus on enabling performance-based operations and demonstrating how SESAR Solutions can be deployed in complex environments.

The solutions resulting from SESAR 1 and common projects, as well as further R & D under SESAR 2020, will contribute to the aforementioned improvements and benefits to be realised through the gradual implementation and deployment of the SESAR Target Concept. Deployment-related decisions will have to be taken in due time by concerned stakeholders on the basis of the confirmed maturity of the related SESAR Solutions.

The SESAR Target Concept is further described in Chapter 4.

2.3 Common Support Services

Common Support Services refer to services that provide ATM capabilities in the same form to consumers that might have otherwise carried them out themselves, thus reducing fragmentation, enabling economies of scale, facilitating synergies and improving safety.

With the development and introduction of new systems over the next decade, several services for collecting, processing, enhancing or distributing data could be implemented as Common Support Services. The rationale for using common services is to reduce the number of times a given service is developed and deployed and to increase the use of more cross-border services to improve cost effectiveness and overall ATM performance. The development of Common Support Services will also result in a more flexible, scalable interface between the system infrastructure and the ANS operations, allowing operational stakeholders to plug in their services where they are needed in the most effective and cost-efficient manner. Areas where Common Support Services may be considered include the following range of established capabilities ([16]), which may be provided primarily to operational stakeholders, on a competitive and non-local basis, by one or more service providers:

([16]) ICAO Doc 9854 (Global Air Traffic Management Operational Concept).

- aerodrome operations;
- airspace organisation and management;
- airspace user operations;
- conflict management;
- demand and capacity balancing;
- information management (e.g. common components such as meteorological and aeronautical information management);
- service delivery management;
- traffic synchronisation.

Examples of ongoing activities related to Common Support Services include:

- services for air traffic flow management, including civil/military coordination;
- services for the collection, dissemination and provision of airspace management data;
- services for flight planning;
- services for airport collaborative decision-making and integration of airports into the ATM network;
- services to provide air picture data across the European ATM Network;
- data communication services for air-to-ground datalink;
- network data services for secured ground-to-ground voice and data exchange;
- aeronautical information management (AIM) services.

3 Performance View

3 Performance View

This chapter outlines the performance ambitions that SESAR may enable through the full implementation of its vision within the 2035 timeframe (see Chapter 2). The performance ambitions are outlined according to several key performance areas (KPAs), including those that have been inspired by the SES High-Level Goals (see Chapter 1) and that have been defined by the SES Performance Scheme.

As the technological pillar of the SES, SESAR is one of the key contributors to the SES High-Level Goals through the delivery and deployment of SESAR Solutions with demonstrated and measurable performance gains. SESAR's performance ambitions are aspirational rather than fixed and binding, since the project has to take into account the lengthy investment lead times common to infrastructure industries like ATM and the need to spur sustained R & D activities for the future. Longer timeframes bring increased uncertainty to the level of performance in the medium to long term. In particular there is uncertainty on traffic evolution, which is accommodated in the SES legislative package through a risk-sharing mechanism. As such, SESAR performance ambitions should be confirmed and adapted, as and when SESAR Solutions are delivered and in some cases should be supported by changes in the way services are provided so as to reach their full potential.

In this context, the SESAR project is expected to contribute to the SES Performance Scheme ([17]). Nevertheless its contribution to the various KPAs described in this section will need to be validated on the basis of the research results for each SESAR Solution and reviewed in the context of the deployment activities that may depend on local circumstances and the availability of sufficient deployment capacity to bring the changes into operation.

([17]) Commission Implementing Regulation No 409/2013 on SESAR deployment governance and common projects, Article 4(2).

3.1 Enabling maximum performance gains

The performance ambition supported by SESAR is aspirational and refers to the performance capability that may be achieved if SESAR Solutions are made available through R & D activities, deployed in a timely and, when needed, synchronised way and used to their full potential. The extent to which all the benefits can be realised in the stated timescales will depend on local circumstances and the availability of sufficient deployment capacity to bring the changes into operation. The application of Common Support Services (e.g. addressing infrastructure rationalisation) is key to achieving the stated performance ambition. This ambition provides a common reference for the ATM stakeholder community with which to define development and deployment priorities. The geographical scope of the performance ambition covers the European Civil Aviation Conference

Figure 5 **SESAR performance ambitions for 2035 (categorised by KPA)**

Key performance area	SES High-Level Goals vs. 2005	Key performance indicator	SESAR ambition vs. baseline 2012: Absolute saving	SESAR ambition vs. baseline 2012: Relative saving
Cost efficiency: ANS productivity	Reduce ATM services unit cost by 50% or more	• Gate-to-gate direct ANS cost per flight - Determined unit cost for en-route ANS* - Determined unit cost for terminal ANS*	EUR 290-380	30-40%
Operational efficiency	-	• Fuel burn per flight (tonne/flight) • Flight time per flight (min/flight)	4-8 min 0.25-0.5 tonne	3-6 % 5-10 %
Capacity	Enable 3-fold increase in ATM capacity	• Departure delay (min/dep) - En-route air traffic flow management delay* - Primary and reactionary delays all causes • Additional flights at congested airports (million) • Networkthroughput additional flights (million)	1-3 min 0.2-0.4 (million) 7.6-9.5 (million) Additional flights, not saving	10-30 % 5-10 %[1] 80-100 %[2]
Environment	Enable 10 % reduction in the effects flights have on the environment	• CO_2 emissions (tonne/flight) - Horizontal flight efficiency (actual trajectory)* - Vertical efficiency - Taxi-out phase	0.79-1.6 tonne	5-10 %
Safety	Improve safety by factor 10	• Accidents with ATM contribution	No increase in accidents	Improvement by a factor 3-4
Security	-	• ATM related security incidents resulting in traffic disruptions	No increase in incidents	

Metrics with monetary value in business view

* Targeted by the Performance Scheme

[1] Additional flights that can be accommodated at congested airports, representing 5-10 % of flights at congested airports (~31 % of14,4 (million) flights in 2035).
[2] Additional traffic accommodated in 2035 in comparison with 2012 and associated with ANSP productivity gains, enabled by SESAR. Note: Numbers are rounded.

(ECAC) ([18]) area as a whole and is expressed as ranges within a 2035 timeframe, due to the underlying uncertainty attached to long-term forecasting. The starting point against which the performance ambitions are measured is 2012, which is the year of the last Master Plan update, the start of the SES Performance Scheme and the year for which the most recent and validated data were available when this work was performed.

The performance ambitions are categorised according to the SES KPAs of safety, environment, capacity, cost efficiency ([19]), as well as operational efficiency ([20]) and security, two further KPAs which have been identified as key within the SESAR R & D framework. These performance ambitions are aligned with the SES High-Level Goals, while also reflecting the evolution of European aviation since 2005, the year in which the SES High-Level Goals were formulated. In particular, network traffic growth forecasts have been reviewed downwards, thus lowering the need (and consequently the ambition) for additional capacity. At the same time, an estimated average reduction of 2 % in real terms of European gate-to-gate ANS costs between 2005 and 2012 has been recognised in this latest performance ambition calculation.

To better reflect the expected evolution of European ATM in the coming years, a reference scenario is put forward for 2035. This scenario is extrapolated by projecting the historical values observed up to 2012 for different KPAs, supposing that SESAR would not be deployed and taking into account traffic forecasts. It acknowledges that, in the coming years, performance gains will be achieved through the effect of the SES Performance Scheme target-setting, economies of scale in relation to traffic growth, and initiatives and/or partnerships at functional airspace block (FAB), State or ANSP level. SESAR will, however, be needed to sustain these performance efforts through time, by providing the overall framework and the specific solutions needed to support collaboration, partnership, rationalisation, and the sharing of best practices.

So while improvements will be achieved under a reference scenario, the implementation of the SESAR vision outlined in Chapter 2 will lead to a paradigm shift that will enable further substantial performance gains.

The SESAR performance ambition levels for 2035, outlined in Figure 5, are subject to the optimal development and deployment of the Operational Changes made possible through SESAR Solutions. These changes and the related priority R & D activities are detailed in Chapter 4, while their benefits are monetised in Chapter 6. These ambitions also take into account the evolution in ATM service provision, which should further facilitate SESAR deployment.

For the purposes of strategic deployment planning set out in the Master Plan, European service provision units have been categorised into four operating environments: airport, terminal manoeuvring area (TMA), en-route and network. Further subdivisions for detailed planning purposes recognise the different needs of units with differing complexity and traffic levels.

The sections hereafter address the individual KPAs in greater detail.

3.2 Cost efficiency to support ANS productivity

SESAR delivers a portfolio of solutions capable of enhancing ANS productivity. In this regard, the ambition is to provide the necessary technical system changes at reduced lifecycle costs, while also developing the operational concept to enhance the overall productivity of ANS provision.

In 2012, gate-to-gate direct ANS costs per flight ([21]) for the ECAC area were approximately EUR 960 ([22]). Meanwhile, according to the 'PRB Annual Monitoring Report 2014', these costs amounted to EUR 820 for the SES area in the same reporting year ([23]).

([18]) The European Civil Aviation Conference seeks to harmonise civil aviation policies and practices amongst its Member States and, at the same time, promote understanding on policy matters between its Member States and other parts of the world. ECAC covers the widest grouping of Member States of any European organisation dealing with civil aviation.

([19]) Commission Implementing Regulation No 390/2013 adopts cost efficiency as the title of one of the four KPAs covered whereas ICAO has established cost effectiveness as a KPA. Cost Efficiency is used here to be consistent with Single European Sky regulations.

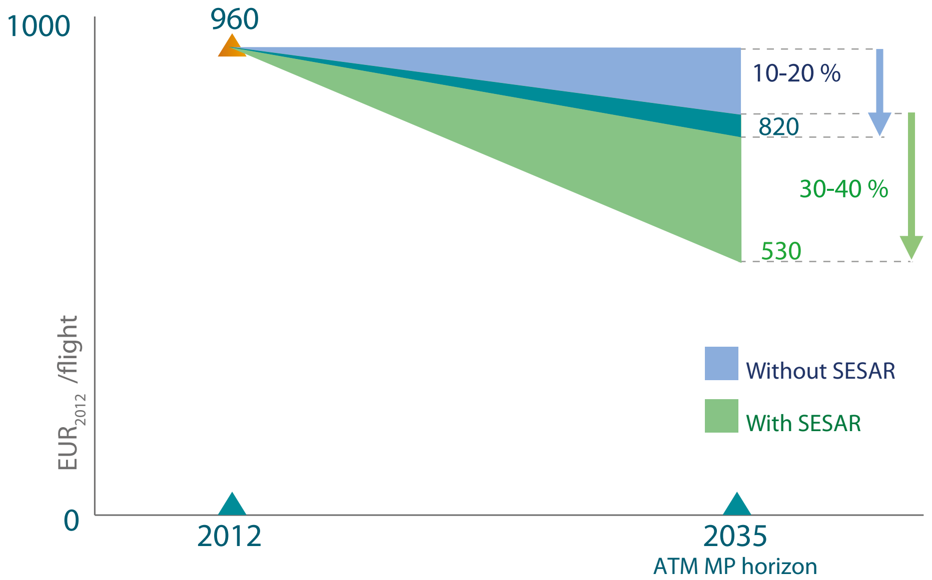
([20]) Operational Efficiency is translated into measurements of delay and fuel savings, in order to be useable by the SES Performance Scheme under the environment and capacity KPAs.

([21]) ANS costs are those defined in Article 6 of Commission Implementing Regulation No 391/2013 (the 'Charging Regulation'). They are composed of costs incurred by ANSPs in the provision of air navigation services (Article 6(1)) and also: (a) costs incurred by the relevant national authorities; (b) costs incurred by the qualified entities referred to in Article 3 of Regulation (EC) No 550/2004; (c) costs stemming from international agreements (Article 6(2)).

([22]) ACE 2012 data, dividing the total European gate-to-gate ANS costs for 37 ANSPs (EUR 9.156 billion) by 9.55 million flights.

([23]) See page 78 of the PRB report, Volume 1. The difference with the ECAC figure for Master Plan purposes is due to: 1) the difference in geographical scope, where the extension from SES to ECAC area brings about 20 % of additional ANS costs and about 4 % of additional flights; 2) the Master Plan includes all terminal

Figure 6 **Evolution of gate-to-gate direct ANS costs per flight**



ECAC area; amounts expressed in EUR_{2012} and in real terms — *Source:* ACE 2012

By 2035, the SESAR performance ambition for the ECAC area is to allow a reduction of 30-40 % (or approximately EUR 290-380) of the cost per flight compared to 2012.

As outlined in Section Section 3.1, in a reference scenario where SESAR is not fully deployed, an estimated cost reduction of 10-20 % (or approximately EUR 100-200) per flight can already be expected by 2035, based on a historical trend analysis. This reduction is expected to come from economies of scale, cost-efficiency measures and further rationalisation processes currently underway within States/ANSPs, underpinned by SES Performance Scheme target-setting. At the same time, performance improvements cannot be completely decoupled from technical evolution: SESAR is an essential component for achieving such performance gains, playing an enabling and supporting role.

For this reason the SESAR performance ambition is not entirely separated from, and partially overlaps (around 5-10 %) with, the reference scenario cost reduction, as indicated in Figure 6.

In terms of the operating environments, the cost-efficiency ambition for SESAR, underpinned by ANS productivity improvements and infrastructure cost reduction, is spread approximately as follows:

- airport: EUR 50-80 per airport air transport movement ([24])
- terminal and en-route: EUR 240-300 per IFR flight

The benefits to ANS productivity are mainly expected from higher automation of routine tasks, improvement of working methods and technologies, virtualisation of ANS allowing optimal resource use across the ATM network, flight- and flow-centric operations and widespread use of data communication.

Lean and efficient use of ANS infrastructure, based on interoperable standards and services decoupled from system specificities will additionally allow lower ATM system-related operational, maintenance and depreciation costs.

The extent to which these gains can be realised depend upon the evolution in traffic growth, the validation of the expected contribution of SESAR Solutions to performance, and whether and how SESAR Solutions will be deployed. It should also be noted that this cost-efficiency ambition does not take into account the cost of change or the possible restructuring costs incurred. However, the impact of such costs is expected to be limited as the cost-efficiency ambition represents approximately an average of 1 % of cost-efficiency gain per year over a 20-year period (in the most optimal deployment option as described in the Chapter 5). The Master Plan aims to facilitate long-term planning in terms of the resources and skills needed, as well as an early implementation

ANS costs whilst the PRB report is limited to those terminal costs within the scope of the charging Regulation (EU) No 391/2013, i.e. in the vicinity of airports with more than 70 000 IFR movements per year; and 3) the use of EUR_{2009} by the PRB, whilst the Master Plan uses EUR_{2012}.

([24]) An air transport movement at an airport can be a departure or an arrival.

of social dialogue. In doing so, it aims to facilitate achieving change at a reasonable cost, spread over a longer period. Some States/ANSPs have already adopted this approach and taken first steps towards this change management.

3.3 Operational efficiency

In addition to the direct gains in terms of cost efficiency, SESAR will also bring indirect economic benefits during flight operations, mainly through the reduction and better management of departure delays and more efficient flight paths, reducing both fuel consumption and flight time, and increasing predictability.

3.3.1 Fuel efficiency

The SESAR fuel efficiency performance ambition primarily addresses [25] the ATM-related fuel consumption within a gate-to-gate scope. It therefore covers efficiency on the airport surface, as well as both horizontal and vertical flight profile efficiency throughout the flight trajectory. The aim is to reduce the impact on fuel efficiency performance while maintaining the ability to accommodate traffic increases in a safe manner. The SESAR performance ambition is to enable an average reduction of approximately 250-500 kg of fuel per flight (i.e. approximately 5-10 % of 4 800 kg of average consumption for a representative flight). This ambition addresses airport surface operations, TMA climb and descent operations and en-route vertical flight efficiency. It is broader than is currently targeted by the SES Performance Scheme, which focuses on the horizontal en-route flight extension only and aims to achieve 2.6 % in flight extension by 2019 compared to the 2012 baseline of 3.2 % [26].

The SESAR ambition of enabling approximately 250-500 kg fuel burn reduction is, on average, most likely to be enabled across operating environments as follows:

- **Airport surface operations:** 38-75 kg fuel burn reduction per flight due to more efficient taxi operations, representing 30 % reduction in average taxi fuel burn per flight.
- **TMA climb/descent operations:** 163-325 kg fuel burn reduction per flight due to the reduction in the use of stacks and/or holding patterns in the descent phase and more efficient climb and descent profiles, representing a 10 % reduction in average climb/descent fuel burn per flight. It should be noted that a significant portion of this improvement relates to TMAs serving the busiest and more congested airports in Europe.
- **En-route cruise operations:** 50-100 kg fuel burn reduction per flight due to more direct cruise trajectories and more efficient vertical profiles, representing a 2.5 % reduction in average en-route cruise fuel burn per flight.

[25] SESAR is also addressing other aspects of environmental sustainability, but these are not yet subject to quantitative targets/ambitions, e.g. a reduction of aircraft noise in the vicinity of major European hubs due to new approach procedures and related technologies. Note also that fuel burn reductions from improvements in aircraft/engine design are out of scope — the ambition is related purely to ATM changes.

[26] Source: PRR 2013 — Horizontal en-route flight efficiency (EUROCONTROL area) based on RP2 KEA metric (the average horizontal en-route flight efficiency of the actual trajectory, defined as the comparison between the length of the en-route part of the actual trajectory derived from surveillance data and the corresponding portion of the great circle distance, summed over all IFR flights within or traversing the European airspace (Commission Implementing Regulation 390/2013)).

Benefits for airport surface operations are expected from enhanced taxi-out management in airport operating environments, particularly at airports where both runway and stand capacity are highly utilised and currently require extended and variable taxi times.

In TMA operating environments, benefits are expected from the reduction in the use of stacks and/or holding patterns in the descent phase and more climb and descent profiles with fewer level flight segments, particularly in the busiest TMAs.

In en-route and cruise operations, fuel burn will be reduced by the use of direct cruise trajectories. SESAR will enable minimal impact on the fuel consumption of trajectory revisions needed for separation.

3.3.2 Time efficiency — shorter flight times

With SESAR, improved flight trajectories will result in a 3-6 % reduction in flight times by 2035 compared to 2012, representing 4-8 minutes on an average ECAC flight with a duration of 127 minutes. This will be enabled by user-preferred routes, dynamic airspace management and flexible airspace configurations, as well as through the advanced use of automation to support tactical air traffic control, allowing the optimisation of traffic flows to and from busy airports.

3.3.3 Time efficiency — reduced delays

2012 is the baseline for projecting the reference scenario, in which departure delays per flight in the ECAC area average approximately 10 minutes per flight (primary and reactionary delays of all causes) ([27]). Of this total, approximately 40 % (or up to 3.7 minutes) is directly or indirectly influenced by ATM factors and weather-related factors. The remaining time delay is associated with, among other factors, airline operational or technical issues, industrial actions and airport security.

The SESAR performance ambition is to be seen in the context of the suboptimal delay situation in 2012 and an additional 50 % in annual traffic volume to be handled in 2035. The calculation assumes that delay growth is linear with traffic in the reference scenario. In this respect, the SESAR ambition is to reduce total departure delays by 1-3 minutes per flight by directly reducing primary air traffic flow management (ATFM) delays (both en-route and airport arrivals), local airport departure delays and their associated reactionary delays. This will be achieved through real-time monitoring of trajectories and collaborative decision-making among stakeholders, who will proactively manage delays in order to minimise their impact on the overall schedule. Other types of delay will also be indirectly reduced, thanks to the increased flexibility in operations management and confidence in network planning.

Combined with the increased predictability described in Section 3.3.4, this SESAR ambition of shortening departure delays will provide the basis for setting the performance ambition for the reduction of arrival delays within the SESAR 2020 framework in response to stakeholders' expressed needs.

3.3.4 Increased predictability

In addition to reductions in departure delays, the SESAR performance ambition aims to increase the predictability of flight arrivals according to commonly agreed reference business trajectories prior to push-back. This predictability is expected to be a key outcome of the deployment of the SESAR Target Concept, which foresees a move to trajectory-based operations (TBO), a more sophisticated network operations planning process and extensive information exchange (see Chapter 4, Section 4.1). Specifically, more predictable arrivals are expected to result from enhanced capabilities to manage a number of factors which cause constraints — key among them are adverse weather conditions and the variability in queuing for accessing congested runways (both arriving and departing).

Expressed in terms of the size of the time window within which 70 % of flights actually arrive at the gate ([28]), the SESAR performance ambition aims to reduce the size of this time window from approximately 5 minutes to 2 minutes, which corresponds to about a 60 % reduction. This in turn will have a beneficial effect on the reduction of the 'buffer time', which airlines factor into schedules in order to increase their robustness to tactical time variations leading to strategic delay costs. The key phases of flight for enhancing predictability are therefore taxi-out and TMA arrival. Approximately 80 % of the predictability ambition is expected to derive from improvements in these areas, with some additional improvements also in taxi-in operations at airports and en-route operations.

([27]) Central Office for Delay Analysis (part of EUROCONTROL NMD).

([28]) A similar indicator has been used in comparisons between EU and US ATM-related operational performance. The use of the 70 % threshold removes statistical outliers.

3.4 Environment

An average reduction of fuel burnt per flight in the area of operational efficiency has a direct environmental KPA in the reduction of emissions. The SESAR performance ambition estimates a total reduction of between 5 % and 10 % in fuel burn per flight, which corresponds to a reduction of 0.79-1.6 tonnes of CO_2 emissions per flight, split across operating environments as described in the fuel efficiency section.

While airport noise is essentially a local concern, it can represent an obstacle to the implementation of ATM improvements that offer other important airport performance gains, such as fuel efficiency. Each airport needs to reduce the environmental impact per flight in accordance with local priorities and trade-offs. Within SESAR 2020, where possible, solutions will address the noise dimension so as to broaden SESAR's global contribution to the sustainability of European aviation and the toolkit it offers. The SESAR 2020 framework will also provide specific indicators and metrics to assess solutions to improve performance in this regard.

3.5 Capacity

This KPA has two components: network traffic throughput and the accommodation of additional flights at high traffic airports.

3.5.1 TMA, en-route and network capacity

The ambition is to increase the network traffic throughput in order to accommodate all the forecast demand with a sufficient margin. In this respect, starting from the suboptimal delay situation in 2012 and assuming 50 % traffic growth by 2035 (i.e. reaching 14.4 million flights per year), the SESAR ambition is to increase network capacity by 80-100 %. Since capacity provision comes at a cost, it is important that it is provided in relation to demand, when and where needed. A more active role in capacity management at network level will help further improve dynamic demand and capacity balancing and significantly reduce current inefficiencies.

SESAR Solutions are expected to enable these capacity enhancements through the following means:

- In TMA and en-route environments, capacity improvements are primarily enabled by enhancements to conflict and separation management and complexity management, as well as increased automation, thereby freeing controllers from routine tasks in order to concentrate on value-added tasks.
- In airspace management and air traffic flow and capacity management (ATFCM), a more dynamic optimisation and allocation of airspace is foreseen to enable all categories of airspace users to access required airspace with minimum constraints. The increased performance of the modern military flying platform entails additional airspace volume requirements (including RPAS), which SESAR Solutions aim to facilitate. An enhanced and more dynamic balance between demand and capacity is foreseen. These aspects are primary contributions realised in the network operating environment.

The ambition of SESAR is to increase the capability across all these areas such that the anticipated growth can be accommodated. It also aims to provide sufficient scalability at key bottlenecks in the network in order to enable reductions in ATFM delays and enhance the potential for more fuel efficient trajectories.

SUCCESS STORY

Alleviating traffic congestion around airports

Today, arriving airport 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.

The SESAR Solution extended arrival management (E-AMAN) allows for the sequencing of arrival traffic much earlier than is currently the case, by extending the AMAN horizon from the airspace around the airport to further upstream. Controllers in the upstream and cross-border sectors, including those in neighbouring FABs, can instruct pilots to adjust aircraft speed before beginning descent, thereby reducing the need for holding. The results from SESAR flight trials show that this solution offers valuable reductions in fuel consumption and CO_2 emissions.

E-AMAN is planned for synchronised deployment at 24 European airports in accordance with Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the Pilot Common Project (PCP).

3.5.2 Airport capacity

In the reference scenario where no action is taken, bottlenecks are expected to develop in locations where there is insufficient terminal area and airport capacity. Based on the most likely scenario for traffic growth, it is estimated that around 1.9 million flights (12 % of the demand) will not be accommodated in 2035 (according to the airports' reported expansion plans). This scenario also sees more than 30 airports operating at 80 % or more of capacity for 3 or more hours per day, compared to 6 airports in 2012 ([29]). Here the issue is not so much a lack of capacity overall, but rather a lack of capacity at the place, time and price needed. This potential lack of airport capacity will have a knock-on effect into other operating environments, which will also need to be managed. Intensive use of saturated airport capacity will adversely impact predictability and punctuality, making performance ambitions all the more challenging.

The SESAR ambition is to contribute to addressing this issue through solutions that will increase airport throughput. In this respect, the aim is to accommodate between 220 000 and 440 000 of the estimated 1.9 million additional flights per year. This is expected to be achieved in two ways, both of which are being addressed by SESAR Solutions:

- enabling an increase in runway throughput per busy/peak hour so that the airport is able to raise the declared capacity;
- reducing capacity degradation (and consequent impact on flight operations) in non-nominal operating circumstances, such as low visibility conditions, strong winds, system or infrastructure issues. This is also addressed by airports operations planning.

The targeted capacity increase will require enhancements to traffic sequencing, reduced separation requirements, reduced and more predictable runway occupancy time, and enhanced management of taxiway throughput for both arrivals and departures. At airports where capacity is constrained by runway throughput, these enhancements will enable a greater number of arrivals and departures to be scheduled by airline operators. The construction of additional runways, rapid exit taxiways and terminal infrastructure would make a significant additional contribution to the overall European airport capacity, but are not within the scope of SESAR.

However, it should be noted that not all airports will need to deploy the same level of capabilities to meet the forecast traffic. The capabilities required will be dependent on runway utilisation and the complexity of the layout at each individual airport. Furthermore, it remains to be seen to what extent the tighter utilisation of airport capacity across the network can be achieved at the same time as significant improvements in predictability and punctuality. These issues will be addressed within the scope of SESAR 2020.

([29]) Challenges of Growth 2013 Summary Report — 2013.

3.6 Safety and security

The performance approach to safety and security is different from other performance areas. By their nature, they cannot be categorised according to operational environments. Regarding safety, in principle each local operating environment will need to reduce the risk per flight by an amount that is at least equal to the local rate of traffic growth, but it would not be meaningful to apply an absolute categorisation, as safety ambitions are expressed purely in qualitative and relative terms. In terms of security, the ambition implies taking all the necessary measures to ensure that from the beginning security is taken into account in the design of each system development lifecycle and that a holistic approach is used to assess the risks.

3.6.1 Safety

Safety improvements are one of the four SES High-Level Goals driving the evolution of ATM in Europe and one of the four KPAs addressed by the SES Performance Scheme.

Irrespective of traffic growth, the ambition is to maintain and, where possible, reduce the level of safety and security risks associated with ATM. This has been a consistent goal for more than a decade and was re-affirmed in the 2nd edition of the Master Plan. It is reflected in the SES High-Level Goals by the fact that risk rises proportionally to the square of traffic density (hence x9 vs. capacity growth x3) ([30]). A substantial number of SESAR Solutions are specifically focused on improving safety performance. Beyond this, all SESAR Solutions, even if not specifically targeting safety gains, are and will remain subject to a positive safety case prior to being validated as fit for deployment.

The safety ambition of the Master Plan is to reduce the risk per flight so that, irrespective of traffic growth, the overall number of accidents per year with an ATM contribution does not increase and can, in fact, even decrease. This ambition implies a significant reduction in risk per individual flight. This is a cornerstone of ATM strategic planning where it is appropriate and possible to measure potential risks. In line with the most recent traffic growth scenarios outlined in Chapter 1, the performance ambition is equivalent to improving safety by a factor of approximately three.

The scope of the safety performance ambition applies to the provision of ATM and ANS. Within the SESAR project, the key performance indicator (KPI), 'number of fatal accidents and incidents with ATM contribution per year', is measured and assessed against a potential outcome in a hypothetical baseline case (where there are no changes to ATM safety, while traffic is allowed to increase). The ambition is then cascaded to drive safety acceptance criteria associated with the operational changes under evaluation.

3.6.2 Security

Adequate security is a major expectation of the ATM community and of citizens to ensure the ATM system, as well as ATM-related information, is protected against security threats. Security risk management should balance the needs of the members of the ATM community that require access to the system with the need to protect the ATM system. In the event of threats to aircraft or threats using aircraft, ATM should provide the relevant authorities with appropriate assistance and information.

The performance ambition for security is to ensure that there is no increase in the risk of having ATM-related security incidents, taking into account the technological evolution of the underlying systems. This will be achieved through incident prevention (i.e. by protecting the system from an attack) and through system resilience to attacks (i.e. normal operations in the event of attacks resume as safely and quickly as possible).

Because of its specific nature, ATM is particularly focused on cybersecurity, which is specifically addressed in Chapter 5 (Section 5.5.4).

([30]) In establishing the SES High-Level Goals a rounded value of 'x10' was applied for the Safety goal.

3.7 Military performance requirements

The military operating environment (MOE) has been created to analyse the contribution of civil-military coordination and interoperability solutions for mission effectiveness and overall network performance. The military's approach is to implement civil capabilities when possible and when those capabilities do not introduce constraints and limitations to higher military functions. While a large portion of civil operations at airports, in TMA and en-route are comparable, military flight operations are substantially different.

Military air navigation service providers (ANSPs) largely share civil performance requirements when providing ANS to General Air Traffic (GAT). The overarching principle is that the deployment of SESAR should not negatively impact on the effectiveness of the missions performed by the military. System interoperability is the basis for solutions/synergies that enable the reutilisation of existing military capabilities. The defence community (States) has always emphasised the prerequisite of military forces having access to airspace for training purposes, air policing and air defence missions, as well as the need to safeguard the ability to access overseas territories from within the European airspace, as and when required. Additionally, efforts should be undertaken to establish processes and mechanisms supporting the ability to demonstrate that an equivalent level of performance of the military system against SESAR ATM/CNS requirements can be achieved.

A qualitative assessment [31] of the impact of SESAR Operational Changes on military performance has been undertaken (see Chapter 4), specifically for GAT operations, in the following areas:

- capacity;
- cost efficiency;
- efficiency;
- flexibility;
- access and equity;
- interoperability;
- security.

(31) Military Impact assessment of ATM Master Plan Deployment Packages and Deployment Scenarios edition date 18-06-2015.

4 Operational View

4 Operational View

The performance ambition set out in Chapter 3 is supported by SESAR through the implementation of a number of Operational Changes realising the SESAR Target Concept.

4.1 SESAR Target Concept

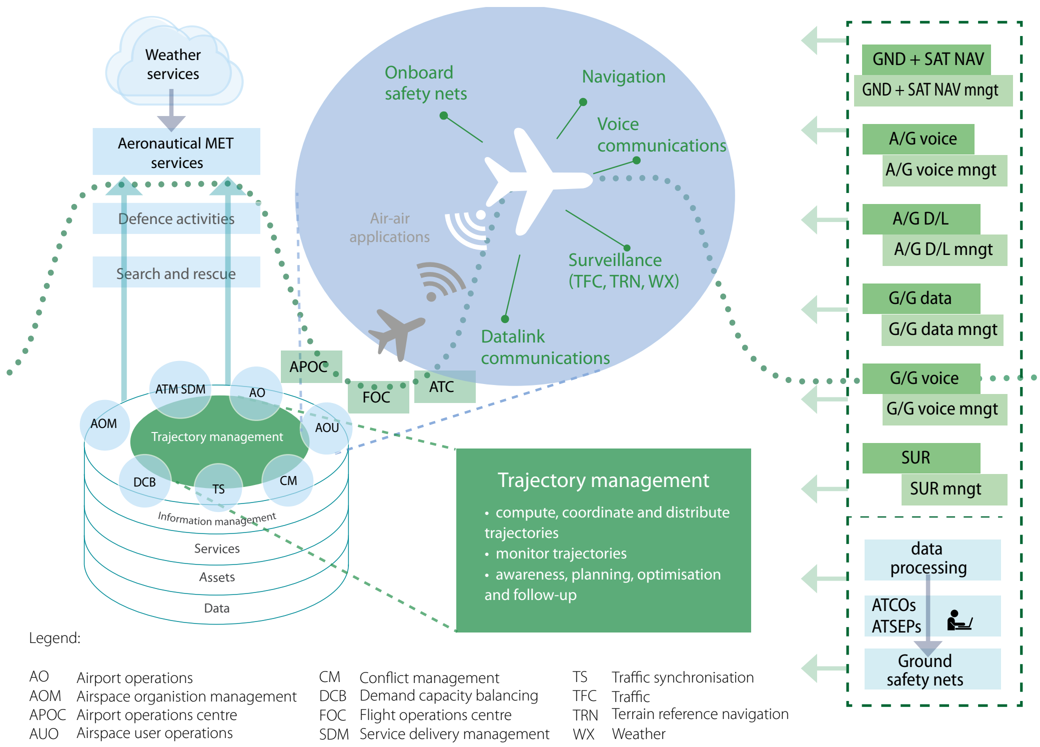
The SESAR Target Concept aims to achieve high-performing ATM by enabling airspace users to fly their optimum trajectories. This concept relies on the effective sharing of information between air and ground actors throughout the business or mission trajectory lifecycle. To do so, airline operations centres, the Network Manager (NM) and air navigation service providers (ANSPs) share trajectory information through system-wide information management (SWIM). Meanwhile, the airborne system receives trajectory information via air-ground datalink and so keeps a fully updated trajectory, as agreed with all actors. The airborne system also enhances the trajectory information maintained in flight data processing systems with aircraft or environmental-specific content downlinked from the aircraft. Figure 7 describes the logical architecture underpinning the Target Concept.

The latest agreed trajectory becomes the reference business or mission trajectory to airspace users, ANSPs and airport operators. This allows all stakeholders, including airports, to have increased predictability of the trajectory, both from the flight data processing system and the aircraft. At the same time, the system's flexibility is retained, since constraints are imposed only when a specific ATM operational need arises (e.g. demand and capacity balancing, complexity management, arrival management or separation management). Flexibility is also key to ensuring a resilient system that is able to deliver to maximum capacity in all situations.

Ultimately European ATM is shifting towards flight- and flow-centric operations, within a network context, allowing airspace users greater flexibility to prioritise their flights and maximise their fleets' performance and meet their business goals. As a result, performance monitoring becomes an integral part of ATM for airspace users but also allows ANSPs to choose which key performance area(s) they wish to prioritise to better serve their customers' needs.

Supporting this paradigm shift is the optimisation of the enabling technical infrastructure, making greater use of standardised and interoperable systems, while advanced automation enables a more cost-effective and performance-based service provision.

Figure 7 **The ATM logical architecture**[32]



4.2 SESAR Key Features

The realisation of the SESAR Target Concept follows strategic orientations described by four Key Features, which evolve through an ongoing R & D programme leading to deployment.

> ***SESAR deployment on the move***
>
> *The most convincing proof of SESAR's readiness was the EU decision to deploy a first set of SESAR Solutions through the Pilot Common Project (PCP) between 2015 and 2024. The PCP will ensure that the solutions derived from the Master Plan and developed by the SESAR Joint Undertaking (SJU) are deployed in a timely, coordinated and synchronised manner by the SESAR Deployment Manager (SDM) in order to bring important performance and cost benefits for Europe's aviation and air transport sectors.*

4.2.1 Optimised ATM network services

An optimised ATM network must be robust and resilient to a whole range of disruptions, including weather and meteorological disruptions. It also relies on having a dynamic, online, collaborative mechanism, allowing 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 SWIM.

4.2.2 Advanced air traffic services

The future European ATM system will be characterised by advanced service provision, underpinned by the development of automated tools to support controllers in routine tasks. The feature reflects this move towards automation with activities addressing enhanced arrivals and departures, separation management, enhanced air and ground safety nets and trajectory and performance-based free routing.

[32] ICAO Doc 9750-AN/963

4.2.3 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.

4.2.4 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. The continued successful integration of

SESAR airport operations centre (APOC)

SESAR is developing a number of solutions within the airport-collaborative decision-making (A-CDM) framework to improve information sharing at airports, thereby improving the efficiency and predictability of flights. One such solution is the airport operations centre (APOC), which brings together the main airport stakeholders to become a platform for stakeholder communication and coordination, based on shared knowledge.

Instead of islands of potentially conflicting decision-making, the APOC provides a coordinated capability, supported by technology and processes, which balances the business priorities and strategies of all airport stakeholders. APOC keeps the airport flowing by matching resources and facilities to changes in demand or schedule.

SESAR validations have shown how APOCs can improve efficiency at both regional and large airports and, in 2014, initial APOCs were opened by SEAC members at Heathrow and Paris Charles de Gaulle airports.

general aviation (GA) and rotorcraft (RC) alongside the introduction of remotely-piloted aircraft systems (RPAS) into the ATM environment is a major activity in this feature.

4.3 SESAR Operational Changes

Operational Changes provide performance benefits (see Chapter 3) to one or more of the four types of operating environment, i.e. airport, en-route, TMA and network.

SESAR 1 comprises:

- Essential Operational Changes (33), which are included in the Pilot Common Project (PCP (34));
- New Essential Operational Changes, defined as those beyond the PCP as well as additional operational changes related to safety;
- Operational Changes that are not currently considered essential.

Figure 8 shows these operational changes, allocated to the operating environments where they bring the most benefit. Each of the Essential Operational Changes supports the performance ambitions identified for one operating environment or more. Other operational changes may be needed, subject to local needs and business cases.

Common projects aim to ensure that solutions contributing to Essential Operational Changes are developed in good time by SESAR and deployed in a timely, coordinated and synchronised manner in order to bring important performance and cost benefits for European aviation and air transport sectors. The first common project is the PCP, which includes the following ATM functionalities:

- extended arrival management (E-AMAN) and performance-based navigation (PBN) in the high density terminal manoeuvring areas (TMAs);
- airport integration and throughput;
- flexible airspace management and free route;
- network collaborative management;
- initial SWIM;
- initial trajectory information sharing.

The Operational Changes are enabled through technical systems, procedures, human roles and institutional changes, including standardisation and regulation. Changes to technical systems are described in ATM Technology Changes, which are an aggregation of changes to individual technical systems.

Roadmaps of all the ATM Technology Changes per stakeholder group are provided in Chapter 5, and indicate the synchronised view (e.g. between ground and air deployments) needed to ensure that their deployment is planned in a performance-driven and fully coordinated way to maximise the benefits for all stakeholders.

Detailed information is given about the ATM Technology Changes required for each new Essential Operational Change (see Chapter 5, Section 5.3) and Figure 15.

The relationship between the four Key Features, Essential Operational Changes and a list of key R & D activities arising from SESAR 2020 are shown in Figure 9.

A high-level description of the evolution of each of the four Key Features from pre-SESAR, through the Operational Changes to R & D activities is provided in Sections 4.3.1 to 4.3.4 with full details of all the Operational Changes available in the European ATM portal (www.atmmasterplan.eu).

A qualitative assessment of the impact on the military (35) has been performed for the new Essential Operational Changes for each of the performance areas described in Chapter 3 (Section 3.7) with the following classifications:

- Neutral = Benefits and cost as planned;
- Negative = Fewer benefits or more cost;
- Positive = More benefits or less cost.

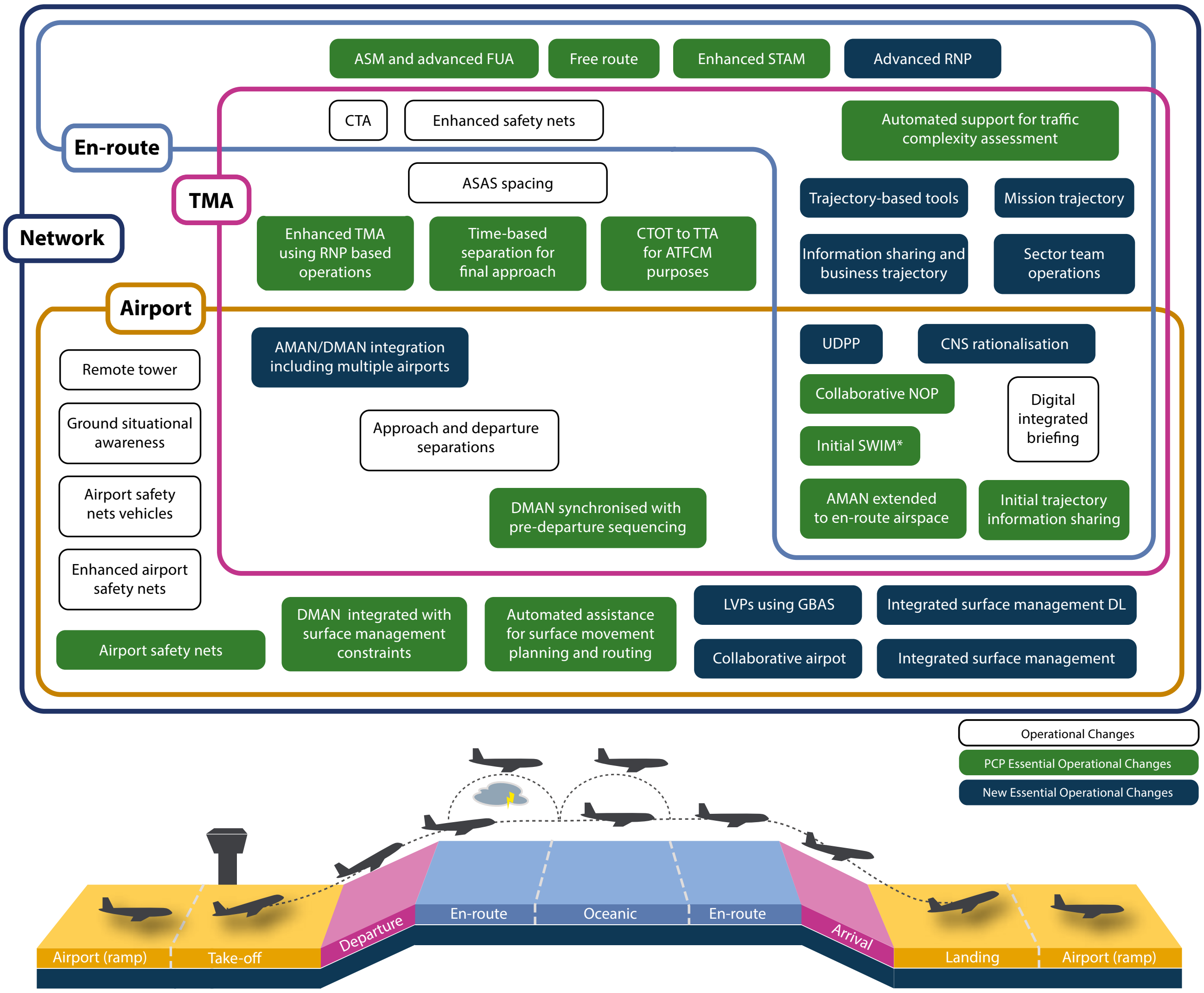
Where the assessment was neutral, this has not been included in the description.

(33) An Essential Operational Change is defined as an ATM operational change that provides significant network performance improvements to the operational stakeholders. An Essential Operational Change is pre-identified in the ATM Master Plan and its performance improvement is validated during the SESAR development phase and then proposed for deployment If these essential operational changes require synchronised deployment to achieve the improved performance at network level and they are mature for deployment, they are proposed as ATM functionalities in common projects as defined in Regulation (EU) 409/2013.

(34) Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the PCP supporting the implementation of the European Air Traffic Management Master Plan text with EEA relevance.

(35) Military Impact assessment of ATM Master Plan Deployment Packages and Deployment Scenarios edition date 18-06-2015.

Figure 8 **Operating environments**



Initial SWIM* includes the following PCP Essential Operational Changes:

- common infrastructure components;
- SWIM infrastructure and profiles;
- aeronautical information exchange;
- meteorological information exchange;
- cooperative network information exchange;
- flight information exchange.

Figure 9 **SESAR Key Features**

	Pre-SESAR	Essential Operational Changes: PCP	Essential Operational Changes: New	Key R & D activities
Optimised ATM network services	• ATFM slot exchange • Civil/military airspace and aeronautical data coordination • Basic network operations planning • STAM	• ASM and A-FUA • Automated support for traffic complexity assessment • Collaborative NOP • CTOT to TTA for ATFCM purposes • Enhanced STAM • Free route	• UDPP	• Management of dynamic airspace configurations • Integrated local DCB processes • Network prediction and performance • Collaborative network management functions • Mission trajectory driven processes • AU processes for trajectory definition • AU trajectory execution from FOC perspective • AU fleet prioritisation and preferences
Advanced air traffic services	• Basic AMAN • Introduction of PRNAV • Provision of ATSA-AIRB	• AMAN extended to en-route airspace • Enhanced TMA using RNP-based operations • Free route	• Advanced RNP • AMAN/DMAN integration including multiple airports • Trajectory-based tools • Sector team operations	• Flight- and flow-centric ATC • High productivity controller team organisation • Collaborative control • Improved performance in the provision of separation • Advanced separation management • IFR RPAS integration • Dynamic and enhanced routes and airspace • Enhanced rotorcraft and GA operations in the TMA • Ad hoc delegation of separation to flight deck • Enhanced airborne collision avoidance for commercial air transport normal operations - ACAS Xa • Use of arrival and departure management Information for traffic optimisation within the TMA • Generic (non-geographical) controller validations
High-performing airport operations	• Initial airport CDM • A-SMGCS L1 and L2 • Crosswind reduced separations for arrivals • Operations in LVC	• TBS for final approach • Automated assistance to controller for surface movement planning and routing • Airport safety nets • DMAN synchronised with pre-departure sequencing • DMAN integrating surface management constraints • Airport operations plan	• LVPs using GBAS • Collaborative airport • Integrated surface management • Integrated surface management datalink	• Wake turbulence separations optimisation • Enhanced arrival procedures • Independent rotorcraft operations at the airport • Traffic optimisation on single and multiple runway airports • Traffic alerts for pilots for airport operations • Enhanced airport safety nets for controllers • Surface operations by RPAS • Enhanced collaborative airport performance management
Enabling aviation infrastructure	• IP network • B2B services • Information reference and exchange models • A/G datalink • ADS-B, WAM • GNSS, GBAS, SBAS	• Common Infrastructure Components: SWIM registry, PKI • SWIM technical infrastructure and profiles • Aeronautical information exchange • Meteorological information exchange • Cooperative network information exchange • Flight information exchange • Initial trajectory information sharing (i4D)	• CNS rationalisation • Information sharing and business trajectory • Mission trajectory	• Integration of trajectory management processes in planning and execution • Performance-based trajectory prediction • Enhanced mission trajectory • Management and sharing of data used in trajectory (AIM, meteo) • Workstation, service interface definition and virtual centre concept • SWIM TI purple profile for A/G advisory information sharing • Airborne D&A systems supporting integrated RPAS operations • FCI terrestrial datalink • Future satellite communications datalink • GA/RC specific CNS systems • GBAS • Multi-constellation/multi-frequency GNSS • Alternative position, navigation and timing
	Deployment			R & D

4.3.1 Optimised ATM network services

Optimised ATM network services

Current situation (pre-SESAR)

- **Air traffic flow management (ATFM) slot exchange** allows airlines to prioritise flights by exchanging the slot of one flight with the slot of another.
- **Civil/military airspace and aeronautical data coordination in real-time** is enhanced through a flexible use of airspace (FUA), which facilitates the flexible allocation of shared airspace resources to civilian and military airspace users.
- **Basic network operations planning** refers to an interactive rolling NOP that provides an overview of the air traffic flow and capacity management (ATFCM) situation with increasing accuracy from strategic planning to real-time operations.
- **Short-term ATFCM measures (STAM)** are aimed at improving the efficiency of the system using flow management techniques through a close working relationship between ANSPs/FMP (flow management position) and the NM.

In the pipeline towards deployment (PCP and New)

PCP Essential Operational Changes:

- **Airspace management (ASM) and advanced flexible use of airspace (A-FUA)** aim to provide the possibility of managing airspace reservations more flexibly in response to airspace user requirements. Changes in airspace status will be shared with all users concerned, in particular the NM, air navigation service providers (ANSPs) and airspace users. ASM procedures and processes will cope with an environment where airspace is managed dynamically with no fixed-route network.
- **Automated support for traffic complexity assessment** involves the use of planned trajectory information, network information and recorded analytical data from past operations in order to predict traffic complexity and potential overload situations, allowing mitigation strategies to be applied at local and network levels. Extended flight plans (EFPLs) will be used to enhance the quality of the planned trajectory information, thus enhancing flight planning and comple xity assessments.
- **Collaborative NOP** consists of increased integration of NOP and AOP information. The Collaborative NOP will be updated through data exchanges between the NM and operational stakeholder systems in order to cover the entire trajectory lifecycle and to reflect priorities when needed. Airport configuration constraints and weather and airspace information will be integrated into the NOP. Where available, the airport constraints will be derived from the AOP.
- **Calculated take-off time to target times (CTOT to TTA) for ATFCM purposes** will be applied to selected flights in order to manage ATFCM at the point of congestion rather than only at departure. Where available, target times of arrival (TTA) will be derived from the AOP. TTAs will be used to support airport arrival sequencing processes in the en-route phase.
- **Enhanced STAM** will enable tactical capacity management, ensuring close and efficient coordination between ATC and the network management function. Tactical capacity management will implement STAM using cooperative decision-making to manage flows before flights enter a sector.
- **Free route** is described in the key feature of advanced air traffic services (see Section 4.3.2).

New Essential Operational Changes:

- **User-driven prioritisation process (UDPP)** gives airspace users the opportunity to exchange the departure order of any two flights from different airlines penetrating the same constraint (airspace volume, arrival airport). This allows airspace users, within commercial agreements, to reduce the delay of a commercially sensitive flight at the cost of another flight. UDPP facilitates ATFCM planning and departure sequences through advanced airport operations (CDM, advanced-dynamic capacity balancing).

  Performance: UDPP provides significant savings to airlines and some additional benefits in flexibility and departure punctuality.

R & D activities

The R & D activities covered by this feature will address the following:

- **Management of dynamic airspace configurations** refers to the development of the process, procedures and tools related to dynamic airspace configuration (DAC). DAC is achieved through a seamless and coordinated approach to airspace configuration, allowing the network to continuously adapt to demand pattern changes in a free route environment and ATC sectors to adapt to dynamic TMA boundaries.
- **Integrated local DCB processes** see the seamless integration of local network management with extended ATC planning and arrival management activities in short-term and execution phases. The solution will improve the efficiency of ATM resource management, as well as the effectiveness of complexity resolutions by closing the gap between local network management and extended ATC planning.
- **Network prediction and performance** relies on shared situational awareness with respect to demand, capacity and performance and has an impact on regional, sub-regional and local demand and capacity balancing (DCB) processes. Prediction of DCB constraints and complexity issues will be based on the definition of metrics and algorithms for prediction, detection and assessment of traffic complexity, thus improving the accuracy and credibility of the diagnosis and awareness of hotspots.
- **Collaborative network management functions** allow for network management based on transparency, performance targets and agreed control mechanisms. The solution enables a real-time visualisation of the evolving AOP/NOP planning environment (such as demand pattern and capacity bottlenecks) to support airspace user and local planning activities.
- **Mission trajectory driven processes** refer to the updating of wing operations centre (WOC) processes for the management of the shared and reference mission trajectory (SMT/RMT). These processes respond to the need to accommodate individual military airspace user needs and priorities without compromising optimum ATM system outcome and the performances of all stakeholders.
- **Airspace user processes for trajectory definition** and **airspace user trajectory execution from flight operations centre (FOC)** allow for the updating and management of the shared and reference business trajectory (SBT/RBT). The processes respond to the need to accommodate individual airspace users' business needs and priorities without compromising optimum ATM system outcome and the performances of all stakeholders.
- **Airspace user fleet prioritisation and preferences** sees the extension of airspace user capabilities, through the UDPP, allowing them to recommend a priority order request to the NM and appropriate airport authorities for flights affected by delays on departure, arrival and en-route, and to share preferences with other ATM stakeholders in capacity-constrained situations (CCS).

Additional R & D activities will address the following:

- **DAC supporting moving areas** will see the management of DAC extended to supporting moving areas. This includes an impact assessment and the integration in the DAC process of areas that are potentially unsafe due to weather phenomena that can evolve in four dimensions.

SESAR synergies with the Network Strategy Plan

The SESAR Essential Operational Changes and the associated ATM Technology Changes led to the development of detailed roadmaps focused on network operations, encapsulating all relevant stakeholder actions. The NM's main aim is to enhance stakeholder understanding of the operational needs of the network in order to expedite and facilitate corresponding implementation actions.

These detailed roadmaps (network evolution, operational and technical) constitute an integral part of the European NOP and were approved for the first time in the NOP February 2015 edition. Through its subsequent updates, NOP will address the new SESAR Essential Operational Changes as they become mature, always focusing on their impact on network operations.

SUCCESS STORY

4.3.2 Advanced air traffic services

Advanced air traffic services

Current situation (pre-SESAR)

- **Basic arrival management (AMAN)** facilitates the use of fixed routes (e.g. precision area navigation-PRNAV) in the terminal area together with the use of CDA approaches.
- **The introduction of PRNAV** procedures capitalises on the performance benefits offered by approved aircraft. This was an interim objective aimed at establishing a global required navigation performance (RNP) area navigation (RNAV) environment.
- **The provision of air traffic situational awareness airborne (ATSA-AIRB)** is considered a precursor of airborne separation assistance system (ASAS) spacing by assisting flight crews in building their traffic situational awareness. This is achieved through the provision of appropriate on-board equipment, including a display of surrounding airborne traffic relative to own aircraft.

In the pipeline towards deployment (PCP and New)

PCP Essential Operational Changes:

- **Arrival management extended to en-route airspace (E-AMAN)** integrates information from AMAN systems operating out to an extended distance to provide an enhanced and more consistent arrival sequence. This requires coordination between ATC in the TMA and adjacent en-route sectors and earlier traffic sequencing in the en-route and early descent phases. Existing techniques to manage the AMAN constraints, in particular 'time to lose or gain' and 'speed advice' may be used to implement this functionality.
- **Enhanced terminal airspace using RNP-based operations** consists of the implementation of environmentally friendly procedures for arrival/departure and approach using PBN in high-density TMAs, e.g. RNP 1 standard instrument departures and arrivals (RNP 1 SIDs and STARs).
- **Free route** may be deployed both through the use of direct routing airspace (DRA) and through free routing airspace (FRA). Direct Routing Airspace is the airspace defined laterally and vertically with a set of entry/exit conditions where published direct routings are available. FRA is an airspace within which users are enabled to fly as closely as possible to their preferred trajectory without being constrained by fixed airspace structures or fixed route networks. In FRA, users may freely plan a route between a defined entry point and a defined exit point, with the possibility to route via intermediate (published or unpublished) waypoints, without reference to the air traffic services (ATS) route network, subject to airspace availability. This Essential Operational Change also applies to the SESAR Key Feature 'optimised ATM network services' (see Section 4.3.1).

New Essential Operational Changes:

- **Advanced RNP (A-RNP)** supports the enhancements of route structures, allowing spacing between routes to be reduced where required, with corresponding requirements on airborne navigation and ground systems capabilities ([36]).

  Performance: A-RNP enables advanced strategic and tactical routing capabilities in en-route sectors, such as spaced parallel routes, fixed radius transitions and tactical parallel offsets, as well as the execution of more predictable aircraft behaviour. These capabilities provide benefits, particularly for DRA and FRA. TMA benefits are already covered by PCP. With A-RNP, the airspace capacity is potentially increased, providing fuel efficiency gains due to better vertical profiles and reduced flight time variability. An expected positive impact on air traffic controller (ATCO) productivity due to more predictable aircraft behaviour should improve cost efficiency. An assessment of the impact on military performance shows the solution to be positive for area control centres (ACCs) in terms of mission effectiveness and flexibility. Military flights accommodated within the airspace

([36]) It should be noted that a regulation is currently being developed by EASA in accordance with Rulemaking task RMT.0639 — Performance-based navigation (PBN) implementation in the European Air Traffic Management Network (EATMN) and the resulting regulation may potentially impact the deployment of Advanced RNP as described.

where A-RNP is implemented will require adequate levels of equipage. Conventional support will be needed for non-PBN aircraft.

- **AMAN/DMAN integration including multiple airports** enables the system to support the coordination of departure (through manual adjustment of the departure sequence) and arrival traffic flows into and out of multiple airports in the same vicinity. This enables a smooth delivery to the runways and en-route phase of flight respectively.

  Performance: Through a better coordination between approach and tower controllers, these capabilities improve the predictability of the off-block time (OBT) and increases airport and TMA throughput. By optimising departure and arrival flows, overall airport delays (arrivals and departures) are reduced, enabling fuel savings. However, this operational change may not bring gains to TMAs and aerodromes which experience only minimum delays and holdings.

- **Trajectory-based tools** support ATC separation management through the deployment of different ATC tools and procedures, such as monitoring aids (MONA), advanced tactical controller tools and 'what-if' capabilities using enhanced trajectory data, e.g. ADS-C extended projected profile (EPP) and trajectory de-confliction tools for multi-sector planner (MSP).

  Performance: The increase in automation support facilitates tactical coordination, increases ATCO productivity and therefore would allow for increased en-route and TMA capacity. Routine tasks, including conformance monitoring, would become fully automated. ATCOs would thus be allowed to concentrate on tasks where human cognitive skills have added value. Where some of the mentioned ATC tools have already been implemented, harmonisation and generalisation of their operational use might bring additional gains.

- **Sector team operations** see the emergence of a new organisational model for controller teams, including new roles and new operating procedures.

  Performance: This new approach is expected to facilitate intra/intercentre coordination and result in more efficient management of ATCO productivity. This has the knock-on effect of substantial increases to en-route capacity, depending on the airspace, ANSP, among other factors. Expected fuel efficiency and flight duration variability gains are related to flight execution within sectors where deviations and additional coordination are not needed.

A number of additional solutions are reaching maturity levels for deployment. Even if they do not comply today with the requirements to be qualified as an Essential Operational Change, they may be considered for deployment at a local level:

- **Airborne separation assistance system (ASAS) spacing** addresses the maintenance of the required time spacing with a designated target aircraft flying either the same route or direct to a merge point during the arrival and approach phases of flight.
- **Controlled time of arrival (CTA)** is expected to increase predictability and TMA capacity as a result of fewer tactical interventions in this phase of flight. The fuel efficiency and en-route capacity benefits are still to be validated pending ground system capability.
- **Enhanced safety nets** enhance the short-term conflict alert (STCA) through the use of aircraft-derived data (ADD). It also addresses the optimisation of safety nets for specific TMA operations.

R & D activities

The key R & D activities covered by this feature will address the following:

- **Flight- and flow-centric ATC** sees the provision of ground-based automated support for managing separation provision across several sectors in order to enable larger sectors to be used. Rather than managing the entire traffic within a given sector. With this solution ATC is responsible for a certain number of aircraft throughout their flight segment within a larger airspace or along flows of traffic.
- **High-productivity controller team organisation** sees the extension of sector team operations beyond team structures of one planning ATCO and two tactical ATCOs both in

en-route and TMA in order to optimise flight profiles, minimise delays and improve ANSP cost efficiencies while taking into account intrinsic uncertainty in the trajectory.

- **Collaborative control** refers to coordination by exception rather than coordination by procedure and is facilitated by advanced controller tools, supporting reduced need for coordination agreements, fewer boundary constraints and the ability to combine sectors into multi-sector planner teams.
- **Improved performance in the provision of separation** aims to improve the separation (tactical layer) in the en-route and TMA operational environments through improved ground trajectory prediction. This is achieved using existing information on lateral and vertical clearances that are known by the ground system, airborne information and data derived from meteorological services.
- **Advanced separation management** aims to further improve the quality of services of separation management in the en-route and TMA operational environments by introducing automation mechanisms.
- **IFR RPAS Integration** provides the technical capability or procedural means to allow RPAS to comply with ATC instructions.
- **Dynamic and enhanced PBN routes and airspace** brings together vertical and lateral profile issues in both the en-route and TMA phases of flight, with a view to creating an end-to-end optimised profile and ensuring transition between free route and fixed route airspace.
- **Enhanced rotorcraft (RC) and GA operation in the TMA** further develops the simultaneous non-interfering (SNI) concept of operations to allow RC and GA to operate to and from airports without conflicting with fixed-wing traffic or requiring runway slots.
- **Ad hoc delegation of separation to flight deck** refers to in-trail follow (ITF) procedures that allow climbs and descents with reduced longitudinal separation minima and in-trail merge (ITM) procedures that enable horizontal merging with reduced procedural separation minima.
- **Enhanced airborne collision avoidance for commercial air transport normal operations (ACAS Xa)** refers to the use of ACAS Xa, an airborne collision avoidance system which takes advantage of optimised resolution advisories and of additional surveillance data, without changing the cockpit interface (i.e. same alerts and presentation in the current TCAS).
- **Use of arrival and departure management information for traffic optimisation within the TMA** sees TMA traffic managed in near real time, taking advantage of predicted demand information provided by arrival and departure management systems from one to multiple airports. This allows the identification and resolution of complex interacting traffic flows in the TMA and on the runway, through the use of AMAN and DMAN flow adjustments and ground holdings.
- **Generic (non-geographical) controller validations** refer to the development of advanced tools and concepts that will help to remove the qualification constraints imposed on ATCOs for controlling a single volume of airspace. This approach would allow ATCOs to operate in any airspace classified as a particular type.

Additional R & D activities will cover the following:

- **Approach improvement through assisted visual separation** refers to cockpit display of traffic information (CDTI) assisted visual separation (CAVS) and CDTI assisted pilot procedure (CAPP) applications that enable aircraft to separate each other visually in marginal visual conditions and that facilitate transitions from IFR operations to CAVS.
- **Extended AMAN with overlapping AMAN operations and interaction with DCB** integrates information from multiple arrival management systems, enabled by SWIM, operating out to extended ranges into en-route sectors using local traffic/sector information and balancing the needs of each AMAN.
- **Management of performance-based free routing in lower airspace** sees the application of FRA for airspace users beyond the PCP expectations, improving predictability, efficiency and flexibility for a wider range of different airspace users.

- **Enhanced ground-based safety nets adapted to future operations** refer to ground-based safety nets for SESAR future trajectory management and new separation modes through the use of wider information sharing.
- **Airborne collision avoidance for RPAS (ACAS Xu)** provides airborne collision avoidance to RPAS, building on optimised resolution advisories and additional surveillance data, while taking into account the operational specificities of RPAS.
- **ACAS for commercial air transport specific operations (ACAS Xo)** improves ACAS, building on optimised resolution advisories and additional surveillance data, while avoiding unnecessary triggering of resolution advisories (RAs) in new separation modes (e.g. ASAS), in particular if lower separation minima are considered.
- **Airborne collision avoidance for GA and RC (ACAS Xp)** provides ACAS to GA and RC, taking into account their limited capability to carry equipment and their operational specificities.
- **Airborne spacing flight deck interval management** refers to new ASAS spacing interval management sequencing and merging (ASPA IM S&M) manoeuvres encompassing the potential use of lateral manoeuvres and involving more complex geometries where a designated target aircraft may not be flying direct to the merge point.

Europe sees benefits of high altitude approach procedures

In 2014, a new and more efficient arrival solution at a high altitude was put in place at Paris-Charles de Gaulle airport for integrating inbound flights using a point merge system.

The solution is built around a merge point located approximately 40 nautical miles from the airport. In the event of high density of traffic, the air traffic controller instructs the pilot to fly on a concentric arc until the aircraft is authorised to join the merge point when the sequencing is most efficient, and to continue its descent path. With no holding pattern, the flight is placed in a direct descent trajectory.

Using existing ground and airborne equipment, SESAR validations showed that the solution enabled the management of more flights simultaneously while in continuous descent, even during heavy traffic periods, thereby offering a more competitive and better quality of service.

Performance-based navigation (PBN)

Today, departure and arrival routes at the airports are based on conventional navigation. This navigation method together with the spacing required between routes is a source of inefficiency. A solution is to implement new procedures based on performance-based navigation (PBN) and the selection of the most suitable navigation specifications for the traffic densities of the European terminal airspace.

A number of projects in SESAR worked on and validated aspects of PBN routes in a terminal airspace, in particular RNP approaches with radius to a fix turns terminating at the final approach fix, the transition from RNP1 to an RNP APCH and from the approach to precision landing, as well as the possibility of reducing route separation or use of tactical parallel offsets for separation. An analysis was also made of the infrastructure required to support PBN and to cater for the loss of navigation signals.

Enhanced terminal airspace using RNP-based operations with RNP 1 SIDs, STARs and transitions (using radius to a fix-RF) and RNP APCH (lateral navigation/vertical navigation (LNAV/VNAV)) is planned for synchronised deployment at the 24 busiest airports in Europe by 1 January 2024, in accordance with Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the PCP.

4.3.3 High-performing airport operations

High-performing airport operations

Current situation (pre-SESAR)

- **Initial airport collaborative decision-making (A-CDM)** improves the overall efficiency of operations at an airport, with a particular focus on the aircraft turn-around and pre-departure sequencing process. It facilitates working together between different partners (airport operators, aircraft operators/ground handlers, ATC and the Network Manager (NM) and allowing the transparent sharing of data.
- **Advanced surface movement guidance and control systems (A-SMGCS) levels 1 and 2** see the deployment of initial airport safety net alerts for ATCOs in the event of runway incursion or intrusion into restricted areas.
- **Crosswind reduced separations for arrivals** refer to ATM procedures that enable ATC controllers to reduce separations under defined crosswind conditions.
- **Operations in low visibility conditions (LVC)** make use of enhanced ATC procedures and/or navigation systems, either through the use of instrument landing systems (ILS) or microwave landing systems (MLS).

In the pipeline towards deployment (PCP and New)

PCP Essential Operational Changes:

- **Time-based separation (TBS) for final approach** sees the application of time-based wake turbulence radar separation rules on final approach for consistent time spacing between arriving aircraft. With TBS, runway approach capacity can be maintained independently of any headwind component. The final approach controller and the tower runway controller are provided with the necessary TBS tool support to enable consistent and accurate delivery to the TBS rules on final approach.
- **Automated assistance to controller for surface movement planning and routing** provides the controller with the most suitable taxi route, calculated by minimising the delay according to planning, ground rules, and potential conflicting situations with other mobiles.
- **Airport safety nets** detect conflicting ATC clearances during runway operations, and non-conformance to procedures or clearances for traffic on runways, taxiways and in the apron/stand/gate area. Airport safety net tools provide appropriate alerts to ATCOs when aircraft and vehicles deviate from ATC instructions, procedures or routes.
- **Departure management (DMAN) synchronised with pre-departure sequencing** delivers an optimal traffic flow to the runway by incorporating accurate taxi-time forecasts into route planning so that target start-up approval times (TSAT) or off-block approved times can be calculated. Pre-departure sequences (i.e. TSAT sequence) are established by tower clearance delivery controllers, who follow TSAT windows when issuing start-up approval.
- **DMAN integrating surface management constraints** refer to the optimisation of the departure sequence according to real traffic situation, reflecting any change off-gate or during taxi to the runway. The solution takes into consideration route planning and route monitoring information, especially taxi-time updates while taxiing for target take-off time (TTOT) and TSAT updates.
- **Airport operations plan** is a single, collaboratively agreed rolling plan available to all airport stakeholders which aims to provide common situational awareness and to form the basis upon which stakeholder decisions relating to process optimisation can be made. As part of the PCP, an AOP is integrated with the NOP.

New Essential Operational Changes

- **Low visibility procedures (LVPs) using the ground-based augmentation system (GBAS)** improve low visibility operations by using GBAS Cat II/III based on GPS L1.

  Performance: With its introduction, technology cost efficiency is expected to improve, while noise abatement benefits are also expected. The impact on military performance is assessed as positive for access and equity for AU, neutral for ATC and positive in terms of interoperability for both the airspace users and ATC at airbases. The priority for the military is to rely on ILS for precision approaches.

- **Collaborative airport** interfaces the landside with the ATM Network. In this framework, airport operations planning, monitoring, management and post-operations analysis tools and processes are built into the AOP and A-CDM for normal, adverse and/or exceptional operating conditions. TTA are derived from the AOP, and are used by NM to balance arrival demand and capacity that will facilitate arrival management processes from the en-route phase. These processes are fully compatible with the NOP and based on SWIM services.

  Performance: Expected direct benefits are increased performance due to better predictability of airport operations and significant resilience benefits through better management of forecast or unexpected capacity shortfalls. It also supports other solutions through the improvement of data accuracy, improved situational awareness and CDM processes throughout the ATM cycle. The impact on military performance is assessed as positive for both security and interoperability for ATC at airbases.

- **Integrated surface management** provides assistance to vehicles (e.g. display of dynamic traffic context information) and to the flight crew by means of taxiway lighting. This is an element of the airfield ground lighting (AGL) operational service providing safe longitudinal spacing between aircraft and vehicles on the aerodrome surface in all weather conditions. The corresponding assistance to controller for surface movement planning and routing is automated.

  Performance: Fuel efficiency and predictability can be significantly improved through the use of AGL and the corresponding solution, namely 'follow-the-greens', which uses speed control to minimise the holding of aircraft and vehicles at intersections and to ensure that they follow the correct route. This will lead to a reduction of speed changes, fewer stops and re-starts during taxiing and a smoother traffic flow, resulting in less fuel burn, reduced environmental impact (noise and particulates) and less taxi-out time variability. The follow-the-greens solution reduces controller and flight crew workload, while situational awareness is greatly improved. Therefore it contributes greatly to surface traffic safety. Military performance impact is assessed as having a positive impact in terms of access and equity for the airspace user and a positive impact in terms of interoperability for both the airspace user and ATC at airbases.

- **Integrated surface management datalink** refers to datalink information exchange between flight crews and controllers and also between vehicle drivers and tower controllers, with improved on-board display of the airport layout, own aircraft position, route and taxi clearances. The information exchange enhances situational awareness for ATCOs, aircraft and vehicle drivers. Enhanced surface management by datalink communications of clearances with mobiles is likely to be an airport decision (subject to local cost-benefit analysis).

  Performance: Minor fuel efficiency gains as taxi times are expected to be reduced due to the improved taxiing phase management, which by means of datalink taxi support (D-TAXI service) could be performed in a more expeditious way without losing time. Operational change dates have been postponed due to datalink technical issues. The impact on military performance is assessed as positive for interoperability.

Furthermore, a number of additional solutions are reaching maturity levels for deployment. Even though they do not currently comply with the requirements to qualify as Essential Operational Changes, they may be considered for deployment at a local level:

- **Airport safety nets for vehicles** can increase situational awareness during airport surface operations by vehicle systems, which can detect potential and actual risks of collision with aircraft and infringement of restricted or closed areas. These new safety nets provide the vehicle drivers with the appropriate alert.
- **Approach and departure separations** aims to improve wake turbulence separation during take-off and final approach based on weather conditions, aircraft characteristics and required surveillance performance. This solution can also detect wake turbulence using either direct measurements made from the ground at critical locations or prediction/detection of wake conducted directly on-board.

- **Enhanced airport safety nets for flight crew** allows on-board systems are enhanced to detect potential and actual risk of collisions with other traffic during runway operations, and provide the flight crew with the appropriate alert.
- **Ground situational awareness in all weather conditions** is further enhanced with the use of automatic dependent surveillance-broadcast (ADS-B) applications which improve the locating of traffic within a controller sector.
- **Remote tower** refers to the provision of remotely-provided ATS for one/multiple aerodromes by a single ATCO or aerodrome flight information service officer (AFISO) from a remote location (i.e. not from a control tower local to any of the aerodromes). The ATCO (or AFISO) in this facility performs the remote ATS for the aerodromes concerned. Remotelyprovided ATS are reallocated to a remote contingency facility as a contingency solution when the local tower (out-of-the-window location) is not available.

R & D activities

The key R & D activities covered in this feature will address the following:

- **Wake turbulence separation optimisation** is based on downlinked dynamic aircraft characteristics. The downlinked information from aircraft for optimising runway delivery is used in order to predict wake vortex and determine appropriate wake-vortex minima dynamically.
- **Enhanced arrival procedures** make use of satellite navigation and augmentation capabilities, such as GBAS and satellite-based augmentation systems (SBAS), to enhance landing performance and to facilitate advanced arrival procedures (e.g. curved approaches, glide slope increase, displaced runway threshold). By doing so, noise is reduced while runway occupancy time (ROT) is optimised. The solution also reduces the need for separation for wake-vortex avoidance.
- **Independent RC operations at the airport** refer to RC specific approach procedures and SBAS-based point-in-space (PinS), which aim to improve access to secondary airports in LVC.
- **Traffic optimisation on single and multiple runway airports** provides tower and approach controllers with system support to optimise runway operations and make the best use of minimum separations, runway occupancy, runway capacity and airport capacity.
- **Traffic alerts for pilots for airport operations** refer to enhancing on-board systems in order to detect potential and actual risks of collision with other traffic during runway operations, non-compliance with airport configuration (e.g. closed runway, non-compliant taxiway, restricted areas), as well as non-conformance to procedures or ATC clearances. In all cases the flight crew are provided with appropriate alerts. Pilots are provided with the appropriate alerts where there is a risk of runway excursion (take-off and landing).
- **Enhanced airport safety nets for controllers** detect potential and actual conflicting situations, incursions and nonconformance to procedures or ATC clearances, involving mobiles (and stationary traffic) on runways, taxiways and in the apron/stand/gate area as well as unauthorised/unidentified traffic. Controllers are provided in all cases with the appropriate alerts.
- **Surface operations by RPAS** facilitate the operation of RPAS at airports and their integration into an environment which is dominated by manned aviation. To the maximum extent possible, RPAS will have to comply with the existing rules and regulations.
- **Enhanced collaborative airport performance management** sees the full integration of the AOP into the NOP, moving towards a total airport DCB process. This involves, among other things, a proactive assessment of the total airport capacity available, including terminal, stand, manoeuvring area, taxiway and runway capacities, and taking into account the prevailing and/or forecast weather and other operational conditions.

Additional R & D activities will address the following:

- **Enhanced collaborative airport performance planning and monitoring** extends the airport performance monitoring process to the airport landside and ground access processes that may have an impact on the airside operations in both planning and execution timeframes. It sees the development of rationalised dashboard(s) fed with all landside and airside key performance indicators and covering total airport management processes.

- **Enhanced guidance assistance to aircraft and vehicles on the airport surface combined with routing** sees the extension of the A-SMGCS routing function to avoid potential traffic conflicts, an improved use of AMAN and DMAN information and integration with total airport management procedures.
- **Enhanced visual operations** refers to enhanced vision systems (EVS) and synthetic vision systems (SVS), which will be developed to enable more efficient taxi, take-off and landing operations in LVC. This is applicable to all platforms — even if main airline platforms have autoland capabilities to facilitate approaches in LVC, they have no capability to facilitate taxi and take-off in order to maintain airport capacity.
- **Enhanced terminal area for efficient curved operations** refers to curved segment approaches as close to the runway as possible to optimise procedures in terms of fuel consumption or noise abatement.
- **Safety support tools for runway excursions** provide controllers and/or pilots with the appropriate alerts where there is a risk of runway excursion (take-off and landing).
- **Enhanced runway conditions awareness** improves safety and situational awareness through the prediction of degraded runway conditions, taking into account different data in order to improve the quality of ROT prediction. ROT prediction will be fed into AMAN/DMAN and surface management tools.
- **Remotely-provided ATS from a remote tower centre with a flexible allocation of aerodromes to remote tower modules (RTM)** will enable the provision of remote tower services to a large number of airports with a flexible and dynamic allocation of airports connected to different RTM over time.
- **Improved access to secondary airports in LVC** will be possible thanks to the introduction of new airborne capabilities, such as RNP and global navigation satellite system (GNSS)-based landing systems.
- **Enhanced navigation and accuracy in LVC on the airport surface** refers to improved accuracy of aircraft navigation during both takeoff and landing operations, as well as improved accuracy for surface movement navigation and service vehicle positioning (using GBAS or SBAS corrections).

Remote tower services no longer a remote dream

Small or local airports are lifelines to local and regional economies, generating mobility of goods, services and people. But keeping these airports open with ATS is a challenge given the costs involved in running them compared to the number of flights they handle. SESAR's remote tower services (RTS) offer new possibilities for places where it is too expensive to build, maintain and staff conventional tower facilities and services, or at airports where such services are currently unavailable.

Using high-definition video cameras together with supporting zoom and infrared cameras, panoramic high-resolution screens give traffic controllers a 360-degree view of an airport, allowing them to remotely provide air traffic and aeronautical flight information services in real time. Like at on-site manned control towers, controllers at their remote workstations have access to information from supplementary sensors and controller tools to ensure that flights take off and land safely and smoothly.

Validation exercises in Norway, Sweden and Germany have shown that RTS are safe and cost-effective, enabling smaller airports to ensure continuity of operations and provide services on demand at single airports. In 2014, the world's first RTS in Sundsvall opened for business, serving Örnsköldsvik airport over 150 km away. Something that began as an idea and a vision of a paradigm shift in air traffic control almost ten years ago has now been realised through close cooperation between SESAR members.

> ***Time-based separation***
>
> *Today, aircraft making their final approach to land are obliged to maintain minimum 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, leading to delays and increased holding at busy times, which in the end results in increased fuel burn and reduced airport capacity. SESAR's time-based separation (TBS) replaces current distance separations with time intervals in order to adapt to weather conditions. SESAR validations have demonstrated that TBS allows up to five more aircraft to land in an hour in strong wind conditions, while reducing holding times by up to 10 minutes.*
>
> *Thanks to TBS, we are seeing increased safety, fewer delays and improved environmental performance. The solution has already seen an early implementation at Heathrow Airport while synchronised deployment of TBS for final approach at 16 airports is foreseen by 2024.*

4.3.4 Enabling aviation infrastructure

Enabling aviation infrastructure

Current situation (pre-SESAR)

- **IP network:** the Pan-European Network Service (PENS) provides a common IP-based network service across the European region.
- **B2B services:** services such as the NM B2B (business-to-business) services.
- **Information reference and exchange models:** system-wide approach to information management and exchanges.
- **A/G datalink:** VDL2 supporting continental ATC services.
- **ADS-B, wide area multilateration:** additional sources of surveillance, enabling rationalisation.
- **GNSS, GBAS, SBAS:** additional means of navigation, enabling rationalisation.

In the pipeline towards deployment (PCP and New)

PCP Essential Operational Changes:

- **Common infrastructure components** consist of:
  - **SWIM registry**, which is used for the publication and identification of information regarding SWIM service consumers and providers, the logical information model, SWIM-enabled services, business, technical and policy information;
  - **Public key infrastructure (PKI)**, which is used for signing, emitting and maintaining certificates and revocation lists. The PKI ensures that information can be securely transferred. All the services described below should be compliant with the applicable version of aeronautical information reference model (AIRM), the AIRM foundation material and the information service reference model (ISRM) foundation material.
- **SWIM technical infrastructure** and profiles include a blue profile for exchanging flight information between ATC centres and between ATC and the NM, and a yellow profile for exchanging any other ATM data (e.g. aeronautical, airport, meteorological).
- **Aeronautical information exchange** will be possible through the implementation of the SWIM technical infrastructure. Services will include notifications related to airspace reservation (ARES), airspace use plans (AUP, UUP) — ASM level 1, 2 and 3; and D-NOTAM.
- **Meteorological information exchange** sees the implementation of services to support airport landside operations, en-route/approach ATC processes and network management.
- **Cooperative network information exchange** sees the implementation of SWIM services such as: airport capacity; NOP/AOP synchronisation; regulations and slots; STAMs; ATFCM congestion points; restrictions; airspace structure, availability and utilisation; network and en-route approach operation plans.

- **Flight information exchange** sees the implementation of services to support the pre-tactical and tactical phases by ATC systems and NM. Services will support various functionalities related to the flight object (FO), which includes the flight script composed of ATC constraints, the 4D trajectory, flight plans, flight performance data and flight status.
- **Initial trajectory information sharing** (i4D) sees the improved use of target times and trajectory information, including where available the use of onboard 4D trajectory data (downlinked for example via ADS-C) by the ground ATC system and NM systems, implying fewer tactical interventions and an improved de-confliction situation.

New Essential Operational Changes:

- **CNS rationalisation** will lead to network optimisation, following the implementation of new functionalities and/or technologies that support higher performance and efficiency (in terms of cost, spectrum, etc). Impact assessments will be made as soon as the new technologies are mature so that old technologies and systems can be replaced/restructured.

  Performance: Cost efficiency gains are expected due to the rationalisation of the existing infrastructures. The impact on military performance is assessed as positive for all KPAs. Military infrastructure and systems can also contribute to CNS rationalisation, leading to a more resilient and seamless European ATM Network and introducing economies of scale. In addition, CNS rationalisation will support the long-term availability of suitable radio spectrum.
- **Information sharing and business trajectory** refers to the initial Reference Business Trajectory (iRBT), which will include all initial shared business trajectory (iSBT) information and will contain, among other information, target times over/arrival (TTO/TTA).

  Performance: Capacity gains in both en-route and TMA airspace are expected to come from improve d network planning and better airspace management. The solution will improve flight predictability, facilitating more efficient business trajectories, which would require less planning and fewer tactical interventions with resulting gains in airspace capacity (en-route and TMA) and in ATCO productivity. Fuel efficiency gains are expected from increased capacity, which leads to reduced delays and therefore fewer reroutings. The impact on military performance, when flying a business trajectory, is assessed as positive in terms of mission effectiveness, airspace efficiency and flexibility for both ATC and airspace users in the ACC and TMA. Within SESAR, information sharing is a critical element for military operations integration and facilitation. It is of upmost importance that interoperability and security solutions are available to enable the appropriate level of data sharing between SWIM and military units/systems, including the aircraft segment.
- **Mission trajectory** is the reference used by all ATM partners during flight execution for flights using ARES airspace. The same flight information as business trajectories is shared. The initial shared mission trajectory (iSMT) will be part of the CDM process, published using NOP with all required data including the allocation of target times. The iSMT will be exchanged with ATC using an improved flight plan. The initial reference mission trajectory (iRMT) will be the partial implementation of the mission trajectory.

  Performance: This solution is expected to improve flight predictability, facilitating more efficient mission trajectories which would require less planning and fewer tactical interventions with resulting gains in airspace capacity (en-route and TMA) and in ATCO productivity. The impact on military performance is assessed as positive for the airspace user across all KPAs: capacity, cost effectiveness, mission effectiveness, airspace efficiency, flexibility, access and equity, security and interoperability in the ACCs. ATC is assessed as positive for mission effectiveness, airspace efficiency, flexibility, access and equity and interoperability. In the TMA, ATC is assessed as positive for mission effectiveness, airspace efficiency, flexibility and access and equity.

Furthermore, a number of additional solutions are reaching maturity for deployment. Even if they do not comply today with the requirements to be qualified as Essential Operational Changes, they may be considered for deployment at a local level:

- **Digital integrated briefing** refers to system improvements made to pilot briefing information on the ground (including at the gate). Accessible on board the aircraft, the digitally enhanced briefing integrates the aeronautical information service (AIS), METEO and other relevant information (e.g. ATFCM, FUA), and is presented in an interactive manner.

R & D activities

The key R & D activities covered by this feature will address the following:

- **Integration of trajectory management processes in planning and execution** refers to the management, negotiation and sharing of the SBT/SMT, as well as the management, updating, revision and sharing of the RBT/RMT, and finally the transition from the SBT/SMT to the RBT/RMT.
- **Performance-based trajectory prediction** refers to data exchange between air and ground and the use of other sources in order to support all advanced operational processes required in SESAR 2020. The solution looks at how the trajectory predictions for ATC, FOC and NM can be improved, taking into account all possible data sources (legacy or not).
- **Enhanced mission trajectory** will be integrated into the TBO environment throughout all phases of trajectory planning and execution (SMT/RMT). Enhanced mission trajectory will be subject to trajectory management processes and contain 4D targets and ATM constraints.
- **Management and sharing of data used in trajectory (AIM, METEO)** will allow greater flexibility to meet the full 4D trajectory management requirements and is expected to come with further proposals on operational, technical and institutional aspects of how aeronautical data should be identified and exchanged.
- **Workstation, service interface definition and virtual centre concept** will provide an operating environment in which different ATS units, even across different ANSPs, will appear as a single unit and will be subject to operational and technical interoperability.
- **SWIM-TI purple profile for air/ground (A/G) advisory information sharing** supports ATM operational improvements that depend on A/G information exchanges to enable better situational awareness and collaborative decision-making.
- **Airborne detect and avoid (D & A) systems supporting integrated RPAS** will replicate the human ability to see and avoid. It is essential that RPAS have this capability as it is one of the cornerstones of aviation called 'rules of the air' in which the pilot is ultimately responsible for the safety of the flight.
- **CNS environment evolution, CNS avionics integration, CNS ground segment integration** will be possible thanks to common system/infrastructure capabilities for both ground and airborne segments:
  - **Future communications infrastructure (FCI) terrestrial datalink**, which includes L-band digital aeronautical communications system (L-DACS) and digital voice.
  - **Future satellite communications datalink,** which enables data communications in oceanic and remote regions and as a complement to terrestrial systems. The development will be carried out in cooperation with the European Space Agency Iris programme.
  - **GA/RC specific communication systems** refers to the development of future communication enablers that are very specific to GA/RC needs and enable their integration into the ATM datalink environment and allow them to benefit from datalink applications.
  - **GA/RC specific navigation systems** refers to the development of future navigation enablers that respond to specific GA/RC needs, allowing for their integration into performance-based airspace.
  - **GA/RC specific surveillance systems** refers to the development of future surveillance enablers that respond to specific GA/RC needs, allowing for their integration into performance-based airspace.
  - **GBAS** sees the finalisation of the development of GBAS CAT III L1 (GBAS approach service type (GAST-D)) in order to maximise the benefits of GBAS technology down to CAT II/III minima.
  - **Multi-constellation/multi-frequency (MC/MF) GNSS** refers to standardisation developments for multi-constellation GNSS.

- **Alternative position, navigation and timing (A-PNT)** provides fallback capabilities in case of GNSS unavailability. A-PNT options could include distance measuring equipment (DME)/inertial reference system (IRS) hybridisation, multilateration and L-DACS mode N.

Additional R & D activities will address the following:

- **GA/RC specific information management systems** refers to functions that are normally expected from a FOC but are made in response to operations specific to GA/RC operations which do not normally have support from FOC/WOC.
- **Workstation controller productivity** sees the development of new human machine interface (HMI) interaction modes in relation to other SESAR Solutions (including new user interface technologies, such as speech recognition, multi-touch and gaze detection).

Other solutions envisaged in the CNS domain include:

- **Future communication infrastructure (FCI) network technologies** sees the migration towards Internet protocol, enabling network-centric SWIM architectures and military interfacing.
- **Development of new services similar to flight information systembroadcast (FIS-B) to support automatic dependent surveillance**, such as broadcast (ADS-B) solutions for GA;
- **Completion of aeronautical mobile airport communications system (AeroMACS) development;**
- **Surveillance performance monitoring**, notably for new surveillance systems wide area multilateration (WAM), multi-static primary surveillance radar (MSPSR), integrated CNS (ICNS), space-based ADS-B;
- **New use and evolution of cooperative and noncooperative surveillance** for ATM and A-SMGCS purposes.

In the SWIM area, other solutions include:

- **SWIM-TI purple profile for A/G safety-critical information sharing,** allowing the distribution of safety-critical information through A/G SWIM infrastructure and aeronautical telecommunications network/Internet protocol suite (ATN/IPS) networking, rather than legacy point-to-point contracted services;
- **SWIM-TI federated identity management,** allowing shareable functions between several users and by other SWIM-TI functions from various SWIM profiles;
- **SWIM-TI common run-time registry,** facilitating the definition of the interfaces for publication, look-up, management and network of registries as well as the definition of non-functional requirements;
- **SWIM-TI green profile for ground/ground (G-G) civil-military information sharing,** ensuring that protocols and data models used in military systems can be interfaced with SWIM with adequate quality of service levels maintained.

First implementation of SWIM-enabled service

SWIM enables seamless information data access and interchange between all providers and users of ATM information data and services. 2014 saw the implementation of Europe's first SWIM-enabled service for arrival management at London Heathrow, as part of the cross-border arrival management (XMAN) trial.

The trial demonstrated that the use of SWIM concepts and technologies can have tangible benefits in terms of reduced development costs and a potential for new services through open information exchange between partners. The Heathrow XMAN service has also been used as part of a SESAR 1 validation exercise on the E-AMAN, a solution which will be deployed across Europe by 2024 in accordance with Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the PCP.

New generation of airport safety nets ready for deployment

With increased air traffic to and from Europe, airports are faced with the challenge of more ground operations and surface traffic moving across runways, taxiways and aprons. SESAR airport safety nets are tools to detect and provide alerts for safety-critical issues (e.g. risk of collision, route deviations, etc.) on the airport surface, and include runway conflicting ATC clearance detection, conformance monitoring alerts for controllers, alerts for pilots and alerts for vehicle drivers.

SESAR validations show that these tools:

- *provide more accurate information on timing and identification of vehicles and aircraft in the ground area;*
- *notify air traffic controllers of the potential runway incursions or area intrusions, and show the real position of vehicles and aircraft in the manoeuvring area;*
- *improve routing calculations and tower supervisor decision-making;*
- *complement already deployed alerts.*

SESAR airport safety nets for controllers are planned for synchronised deployment in a total of 24 airports in Europe by 2021, in accordance with Commission Implementing Regulation (EU) No 716/2014 of 27 June 2014 on the establishment of the PCP.

4.4 Safety nets

Safety nets are considered important within the ATM system as they play an essential role in the mitigation of safety occurrences. The following safety net-related operational changes have been identified for the next deployment wave:

- **Airport safety nets for vehicles** increase situational awareness during airport surface operations by vehicle systems, as they detect potential and actual risks of collision with aircraft and infringement of restricted or closed areas. The vehicle driver is provided with the appropriate alert.
- **Enhanced airport safety nets for flight crew** increase situational awareness during airport surface operations through on-board and tower systems, allowing operations in LVC. The on-board system detects potential and actual risk of collision with other traffic during runway operations and provides the flight crew with the appropriate alert.
- **Enhanced safety nets** enhance the ground-based safety net (STCA), through the use of aircraft derived data (ADD). They also address the optimisation of safety nets for specific TMA operations.

4.5 Remotely-piloted aircraft systems

The emerging technology of RPAS, formerly mostly operated by military agencies, is increasingly used to provide non-military aviation services (commercial, non-commercial or governmental non-military) and is expected to boost industrial competitiveness, promote entrepreneurship and create new businesses in order to generate growth.

RPAS themselves comprise multiple systems with a great variety of equipment and payloads. Beyond the RPAS manufacturers and system integrators, the RPAS industry also includes a broad supply chain providing a large range of enabling technologies (e.g. flight control, communication, energy, sensors, telemetry, etc.). The development of operational and technical SESAR Solutions for RPAS could also create spin-offs with a potential impact on manned aviation, increasing safety, efficiency and reducing environmental impact.

One basic principle underpinning the integration of RPAS, in alignment with ICAO principles, is that RPAS have to be treated in a similar manner to manned aircraft while duly considering the specific character of remotely-manned operations. RPAS operations have to be compliant with aviation regulations, and their integration into the ATM system should not impact current airspace user operations and levels of safety. RPAS behaviour should therefore be equivalent to manned aviation and should comply with the CNS requirements applicable to the class of airspace within which they are intended to operate.

RPAS should also comply with evolutions in the ATM operational concepts currently being researched within SESAR (e.g. trajectory management) as they are deployed.

A principal objective of the aviation regulatory framework is to achieve and maintain the highest possible, and uniform, level of safety. RPAS should be designed, manufactured, operated and maintained in such a manner that the risk to people on the ground and other airspace users is at an acceptable level. Achieving the full integration of all types of RPAS requires the development of appropriate aviation regulations. Across Europe, the current levels of maturity, regulation, standardisation and technology differ from State to State and need to evolve in parallel and in a fully harmonised manner.

The full potential of RPAS can only be realised if these aircraft become an integral part of the aviation system. This will require close coordination ([37]) ([38]) between the R & D activities and regulatory framework so that newly validated technologies can be seamlessly translated into the required legal instruments, industry standards or guidance material. The European Commission will ensure this close coordination and is working towards a strong regulatory framework that will enable drone operations in the EU as from 2016 ([39]). The RPAS research activities stem from a specific analysis of RPAS needs. Technological gaps have been identified in six areas:

- detect and avoid systems and operational procedures;
- data communication links, including spectrum issues;
- surface operations, including take-off and landing and integration into ATM and airspace environments;
- contingency;
- human factors;
- security issues.

Since not all key technologies required for RPAS to fly in non-segregated airspace are currently mature and standardised, RPAS integration into all types of airspace will be gradual and will evolve as technology, regulation and societal acceptance progress. For this reason it is difficult to address all of the issues simultaneously, and the EU RPAS Roadmap provides a prioritised timeline for achieving full integration. The early focus should be on achieving integration with IFR operations in managed airspace and therefore research is also required into collision avoidance (detect and avoid), as well as into command and control (C^2) performance.

([37]) Chaired by the European Commission, the steering group consists of European Aviation Safety Agency (EASA), SESAR Joint Undertaking (SJU), EUROCONTROL Joint Authorities for Rulemaking on Unmanned Systems (JARUS), European Space Agency (ESA), European Defence Agency (EDA), EUROCAE, Association of European Research Establishments for Aeronautics (EREA), European Cockpit Association (ECA), AeroSpace and Defence Industries Association of Europe (ASD), UVS International

([38]) Communication from the Commission to the European Parliament and Council (COM2014-207).

([39]) The Commission builds on the Riga declaration on RPAS (drones): 'Framing the future of aviation — Riga, 6 March 2015' to arrive at common EU rules.

4.6 Mapping to the global context

4.6.1 Harmonisation between SESAR and NextGen

As two of the major aviation modernisation programmes in the world, the NextGen programme of the Federal Aviation Administration (FAA) and SESAR have a shared interest and responsibility in harmonisation as a means of ensuring global interoperability. The two programmes have common challenges and a similar conceptual and performance-driven approach. It is widely understood that systems will not be completely identical but harmonised and interoperable at the standard level. SESAR and NextGen advocate a 'not-one-size-fits-all' approach in both the US and in Europe as well as at ICAO level. This is globally accepted and the aim is to achieve the degree of harmonisation necessary to

- ensure aircraft can operate in all regions. ([40]);
- ensure that common standards are available when needed and in time for both development and implementation planning;
- optimise development and implementation costs through the sharing of effort and results.

The scope of what should be harmonised is derived from the agreed ICAO global ATM operational concept developed by the entire global aviation community and complemented with new requirements expressed by the ATM stakeholders, in particular airspace users.

The US-EU Memorandum of Cooperation (MoC) on civil aviation research and specifically Annex 1 on SESAR-NextGen interoperability is the important vehicle for harmonisation between these two major modernisation programmes and their results directly contribute to the development of global harmonisation initiatives under the umbrella of ICAO, the industry standardisation bodies of RTCA and EUROCAE, as well as with other relevant international standardisation organisations. The MoC as such also constitutes the collaborative framework within which the US and the EU develop and establish joint or supporting positions on standards and priorities in the ICAO work programme, while allowing other regions to share information and where possible participate in the different domains of the MoC.

([40]) Without requiring additional equipment

The SESAR and NextGen programmes are aligned with and support ICAO's Global Air Navigation Plan (GANP) and the Aviation System Block Upgrades (ASBUs). The two programmes both impact and are impacted by the GANP in terms of ICAO priorities. Looking ahead, the focus is to further align the two programmes' priorities supporting a further evolution of the GANP, namely its update in 2016 and 2019.

High-level frameworks have been established and are now being complemented with further agreements at a more detailed level (e.g. harmonised planning and standard proposals to industry standardisation organisations and ICAO). More concretely, the following areas of Annex 1 on SESAR-NextGen cooperation are of particular interest in terms of harmonisation towards global interoperability:

Transversal activities

- creation of a common high-level functional architecture;
- alignment of the standardisation roadmaps towards ICAO GANP work programme priorities;
- a common framework for agreeing or supporting joint positions in the ICAO work programme, which allows the involvement of other regions as agreed and requested;
- alignment between the NextGen Implementation Plan and the European Master Plan, and necessary elements for industrialisation and deployment, including business cases, economic assessments and performance cases;
- integration of RPAS into the ATM system;
- creation of a cybersecurity framework, in particular in the light of increased automation and the SWIM framework which allows for the sharing of information, such as flight plans, aeronautical and weather information and performance data.

SWIM

- agreement on the SWIM concept of operations already delivered to ICAO and which is now the baseline for the recently started information management panel (IMP) in ICAO;
- agreement on data exchange models and service models towards ICAO and global interoperability.

Trajectory management

- agreement on trajectory-based operations (TBO) as the framework for flight planning and execution in a collaborative SWIM-enabled environment, directly related input to the work of the ICAO ATM requirements and performance panel (ATMRPP) on flight and flow information in a collaborative environment (FF-ICE).

CNS and avionics

- development of a shared avionics roadmap for all airspace users;
- better understanding of data communications in terms of current applications and technologies and those needed in the future. These include physical links, networking protocols and services taking into account a foreseen multilink environment, software radios and flight management system capabilities interfacing with flight data processing system capabilities;
- ACAS developments;
- ADS services and technologies harmonising development of ground surveillance applications based on ADS-B and the evolution of airborne ADS-B systems to meet the needs of both the ground surveillance applications and the ASAS applications;
- application of GNSS and the underlying navigation technologies and avionics capabilities.

Collaborative projects

- collaborative demonstrations, such as SWIM global demonstrations and i4D trials.

SUCCESS STORY

NextGen and SESAR collaborate

The US-EU joint harmonisation work ensures that modernisation and advances in air navigation systems worldwide can be made in a way that supports global cooperation, clear communication, seamless operations and optimally safe practices.

In 2014, NextGen and SESAR published a joint State of Harmonisation Document, providing a high-level summary of the current state of progress towards achieving harmonisation and the necessary level of interoperability between the two programmes. This document will be updated with the latest results of SESAR and NextGen in time for the ICAO GANP 2016.

4.6.2 Mapping SESAR changes to the ICAO framework to enable interoperability

The ICAO framework is set through the GANP (Doc 9750) and ASBU initiative, which comprises a set of ATM solutions or upgrades that exploit current equipage, enable a transition plan and allow for global interoperability. ASBUs comprise a suite of modules organised into flexible and scalable building blocks, where each module represents a specific, well bounded improvement. The ASBU initiative describes a way to apply the concepts defined in the ICAO global ATM concept (Doc 9854) with the goal of implementing regional performance improvements leading to overall global performance.

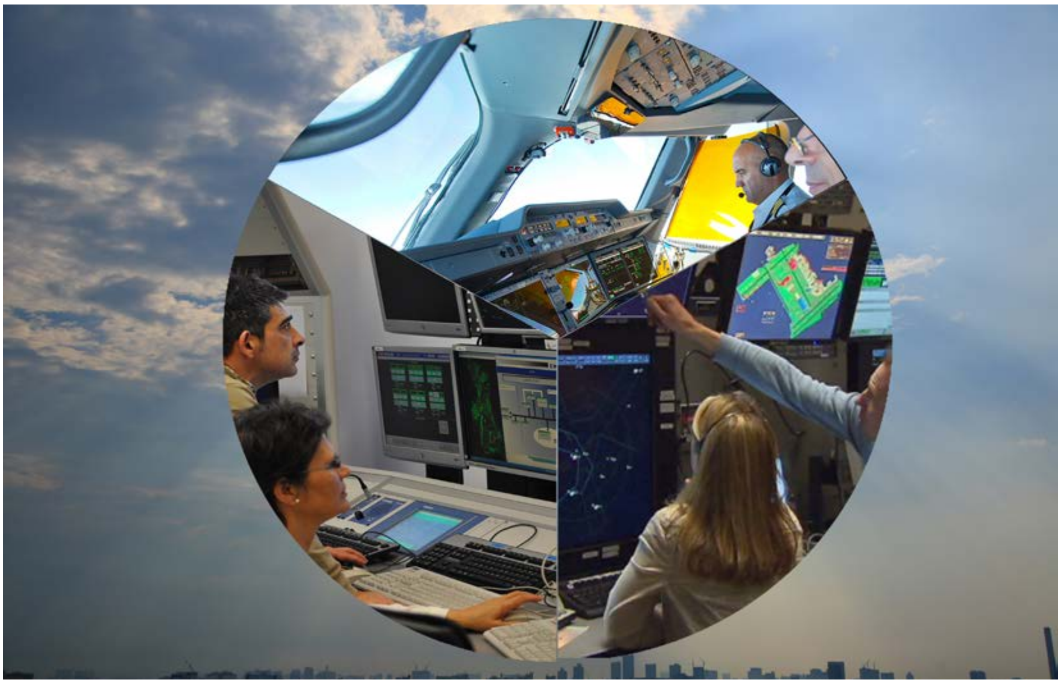
For the development of ASBUs, ICAO made use of material provided by SESAR and NextGen. From a SESAR perspective, mapping ICAO's ASBU initiative is therefore important to facilitate global interoperability and synchronisation where and when necessary. To support global interoperability, it is necessary that the operational achievements in the Master Plan are consistent with the elements in the ASBUs. The mapping between SESAR Operational Changes and ICAO's blocks is provided in Annex A.

It should be noted that SESAR and NextGen through the US-EU MoC were main contributors to the ICAO GANP/ASBU modules and continue to support ICAO through their latest results, shared and joint positions and close cooperation with other regions of the world.

4.7 Role of the human

4.7.1 Integrated view of the ATM system

Realising the vision of the Master Plan will only be possible by recognising human actors as integral to the overall ATM system, and as the most critical source of its performance, safety and resilience. As in past and present operations, ATM performance will remain the result of a well-designed interaction between human, procedural, technological, environmental, organisational and other elements. Given the expected increase in capacity and complexity of European ATM, SESAR will succeed only when the design is understood from an overall system view. The nature and unique adaptability of human performance will, according to the SESAR Target Concept, enable the ATM system to react to variabilities in operational conditions and other non-standard



situations. However, due to the increasing degree of automation support, the interaction between humans and systems, as well as between various human roles will continuously change, with a view to ensuring safe, secure and effective operations in the constrained environment of European airspace and aerodromes.

Around 300 000 operational staff across the aviation sector will be affected by the realisation of the Master Plan. Although this is expected to mostly affect ATCOs, pilots, avionics engineers, air traffic safety electronics personnel (ATSEP) and dispatch roles, the impact on all operational roles should be considered in the development and deployment process. The immense amount of automation and other advanced tools will not only affect operational work itself, but will also have a major impact on all engineering roles in the system.

To support human system integration, the following are key:

- Designs should incorporate an understanding of how human and system actors work together.
- Designs should explicitly incorporate the requirements that enable all functions to work collaboratively in managing:
  - performance variability and system resilience, with a view to sustaining the defined performance;
  - a systematic change-management approach to development, deployment and validation.

In SESAR, human system integration is supported by a comprehensive safety assessment approach, as well as a systematic analysis and management of human factor aspects in the design and validation of future operations, encompassing elements of resilience engineering. A set of methods and tools have been developed to support this integration.

The mandatory SESAR human performance assessment explores potential impacts in the area of human performance ([41]). In the broadest sense this encompasses human system interaction, interaction between humans, human role and responsibility definition, training, staffing, etc. However, it also encompasses the characteristics of the activity that the system is designed to deliver and how it is able to adapt to performance variability. It facilitates the highlighting of critical issues concerning the interaction of humans with all other system elements, derives required human performance (i.e. system-related requirements in the course of development and validation), and thus enhances the maturity of the concepts and technologies by integrating human performance into the design process.

This assessment ensures that:

([41]) The expression 'human performance' refers not to a decomposition of the human as a vulnerable and unreliable system component, but in the specific context that the way a human works within a human system is significantly influenced by under-specification of the structural and procedural system design and the performance variability that the human system is confronted with. The human adapts to these stressors upon the system and provides the means to sustain system operations.

- the role and function of the human, within the human system will be designed so as to enable them to be undertaken in a collaborative and joint manner (i.e. a joint cognitive/collaborative system);
- technical systems will support the human actors operating jointly and specifically in terms of common ground (mutual knowledge), inter-dependability and directability (i.e. effective coordination underpinned by clear and unambiguous authority in joint activity);
- team structures and team communications will support humans in performing their tasks, and human interaction with non-human system elements;
- human performance-related transition factors are appropriately and sufficiently accounted for and include a holistic approach to implementation that avoids negative training effects, e.g. staffing, selection and training impacts.

4.7.2 Changes and issues

Regarding the scope of the Master Plan, the most significant changes to human roles and tasks, identified by the human enablers as part of the implementation roadmap, are summarised in Figure 10.

From the analyses performed so far in the scope of SESAR changes, the most critical general issues with regard to the human role in ATM can be seen in:

- Automation: The dedicated support tools (automated) are fundamental to the successful introduction of the SESAR Target Concept. This is in order to keep workload within acceptable limits, reduce human errors and increase situational awareness. Some key operations are only possible with the support of automation. However, automation is far from being 'one size fits all' and has to be adequately tailored to the operations and the tasks. In particular this must take into account the balance between the efficiency created through automation and human capability (assisted by more basic functions). This is particularly valid for recovery from non-nominal and/or degraded modes of operation.
- A potential redistribution of responsibilities between human roles (Pilots, ATCOs, ATSEPs) including those responsible for system maintenance and oversight. Introducing new complexities and system variability as each function develops will involve differing combinations of human and system working together and interacting functionally.
- A continued expectation that the human role will manage unexpected events. Transition from legacy to SESAR systems, including their concurrent operation or cascade failures leading to deviations from planned trajectory execution, requiring an integrated view of the system design and the interaction of its various actors.
- Possible ambiguities resulting from a redistribution of authority between human and system actors. These will have to be managed by careful procedure design accompanied by a clarification of liability issues.
- The need for carefully designed system-upgrade training for all affected humans, revising and refining the distribution of responsibilities and interactions between them.
- An increased need for continuation training of humans to maintain the skills needed to deal with complex and unexpected events and to prevent skill decay due to a higher degree of automation.
- An increased need for proactive technical training to address the high complexity and rising cybersecurity needs of the SESAR systems while maintaining legacy systems in operation.
- Potential social issues by redistributing responsibilities and changes to the business model of ANSP operations within the European ATM system.

4.7.3 Approach to change management

The changes to be introduced during the SESAR development and deployment phases require a successful transition of the affected staff from the current to the new system. In order to retain the level of service, both a different approach to operation/management and leadership are required, as well as the participation and involvement of staff and management in an effective partnership.

The key enablers contributing to the success of the SESAR development and implementation phases have been identified as follows:

- **Staff involvement**: The effective participation and active involvement of the European civil and military aviation communities, including trade unions and professional staff organisations, within the SJU R & D activities and also within the forthcoming deployment activities, will enable proactive identification of social and change risks and opportunities towards the common goal of improving the overall performance of the ATM system. The

Figure 10 **Overview of the most significant input for human tasks and responsibilities**

Operational change	Start of deployment	Human roles	Main changes
ASAS spacing	2018	New task for flight crew	Enhance human machine interface (HMI) to assist the flight crew in the implementation of spacing tasks supported by tools to automate the manoeuvre.
		Change of air traffic controller task through introduction of separation assistance	Enhance HMI and tools to support the ATCO with ASAS.
Sector team operations	2015	New staffing configuration/Multi-sector planner, extended ATC planner in en-route	Enhance HMI and planning tools to support the new staffing configuration, moving from one tactical and one planning controller to two or more tactical supported by one planning controller in en-route sectors.
		New staffing configuration/ Multi-sector planner, extended ATC planner in TMA	Enhance HMI and planning tools to support the new staffing configuration, moving from one tactical and one planning controller to two or more tactical supported by one planning controller in the TMA.
		New staffing configuration/Single person operation	Enhance HMI and tools to support single person sector operations.
Collaborative airport	2015	New communication and interaction patterns between stakeholders of airport operations linked to collaborative rolling AOP/NOP management	New communication paths and information sharing for the rolling AOP/NOP.
		New role of APOC supervisor	Role responsible for initiating and leading the APOC process that monitors the AOP and the associated decision-making process when important deviations are detected.
		New role of APOC representative will be created from: • airport operator • ground handling agent • airspace user • ANSP	Each will be responsible for coordinating with all other AOP stakeholders.
		Tasks transfer from AOP stakeholders to Airport performance assessment monitoring system (APAMS)	In the new APOC decision-making process, some tasks like the proposal of pre-planned common solutions to adverse situations will be transferred from existing human roles to the APAMS.
		New interactions and communication patterns for the integration of landside process outputs into the A-CDM process	New communication paths and information sharing between Ground Handling Agent and all other A-CDM stakeholders to provide landside information (e.g. passenger and baggage) that can affect ATM performance for the appropriate stakeholders.
		New working methods for the integration into the A-CDM process of • landside operations • airport transit view (ATV)	Working methods will be adapted/revised for ANSPs, NM, airport operators, ground handling agents and airspace users to integrate the appropriate information into the A-CDM process.

involvement of humans in validation activities and simulations (e.g. through the international validation team) will support the maturity of developments.

- **Social dialogue:** Social partners in the European Sectoral Social Dialogue Committee for Civil Aviation will ensure that all affected parties are properly represented and will take a proactive and supportive role to ensure the successful implementation of the SESAR Target Concept through stable participation structures and clearly defined mandates.
- **Change management strategy:** A clear change management strategy and associated planning to initiate, implement, manage and steer effective and sustainable change and transition within an organisation should be established before SESAR deployment. A strategic plan should be developed to include a clear statement of the objectives of the change, timescales, necessary resources, a communication plan, a description of how the affected staff will be involved in the execution of the plan as well as associated risks (e.g. staff involvement in the deployment activities, the establishment of a social forum at European, FAB, national, and company level, etc).
- **Consideration of the effort and costs associated with changes to the role of the human:** This may cover training staff, training development, technical training involving staff in simulations and procedure design, training infrastructure development along with the operational and technical developments. To avoid a negative impact on staffing and consequently on ATM capacity, the effort and cost associated with these activities must be integrated into business cases related to SESAR deployment.
- **Provisions:** These will be made for the training needs that enable effective and optimal change management. This will support a transition path that considers the influence of successive migratory implementation steps towards the agreed concept evolution and minimises the extent to which the human system relies on phenomena such as mode switching.

5 Deployment View

5 Deployment View

This chapter provides an insight into how the SESAR vision could be deployed (see Section 5.1). The deployment scenarios for Essential Operational Changes are presented in Section 5.2 with the necessary ATM Technology Changes provided in Section 5.3. Stakeholder and infrastructure deployment roadmaps are provided in Sections 5.4 and 5.5. The avionics roadmap is included in Annex B. All dates, with the exception of the PCP, are potential dates for deployment. All deployment dates are subject to further considerations after business cases have been developed and validated.

5.1 How and when the SESAR vision can be deployed

The objective of deployment is to realise as many benefits as early as possible, with optimal cost-efficient and effective investments, as well as optimal change management. This requires synchronisation and coordination of investments, supported through EU funding. As automation, integration and harmonisation are key to the vision, early standardisation and a broad engagement of both private and public stakeholders, already during the R & D phase, will contribute significantly to a successful network-wide roll-out. In order to realise the vision and the roll-out of SESAR, two distinct high-level options are put forward (see Figure 11). Both options take into account the SESAR deployment strategy and the designation of a SESAR Deployment Manager (SDM) as responsible for the deployment of common projects. There is however a key difference between the two options, relating to the level of coordination before and during deployment, as explained in Figure 11:

- **Option 1:** optimised ATM infrastructure deployment: deployment with strong, network-wide coordination
- **Option 2:** local deployment: deployment with light coordination

For some SESAR Solutions, there will be little difference between the two options. For example, network-wide optimisation is likely to have a limited impact on deployment for solutions related to airports. On the other hand, for a large number of other solutions, the choice of the deployment option is likely to have a significant impact on overall timing, investment ambition and performance gains, as outlined in Figure 11. Also, network-wide coordination can widen the scope of ANS infrastructure rationalisation and significantly reduce the overall timeline of deployment for new solutions. The choice between both options will be made when a new technology is mature for deployment, in the context of the common projects, based, inter alia, on the results of the development phase.

Figure 11 **High-level options for rolling out SESAR**

Common across options	▪ **Target vision** with standardised SESAR Solutions (automation, system integration, harmonisation, etc) ▪ Need for coordinated timing of investment to ensure **synchronised deployment** (coordinated deployment and incentivisation) ▪ Proactive engagement in **standardisation during the R & D phase**

1. **Optimised ATM infrastructure deployment** is aimed at realising the target vision in an ambitious timeframe for an optimised investment. This option has four key characteristics:
    1. The option is taken into account already during R & D phase, where the architecture and design of solutions already anticipate a top-down, optimised, deployment scenario. Networkwide coordination is also implemented to optimise certain key investments. This implies identifying and explicitly targeting the locations where all SESAR Solutions should be deployed, and therefore also where they do not need to be deployed. This option takes a regional view and assumes a high degree of integration, notably for en-route services. This implies a certain degree of ANSP cross-border integration and assumes a minimum level of civil-military integration, which would in itself also generate synergies and additional cost efficiencies.
    2. There is a need to consider the scope of common projects to enable and facilitate the evolution of ATM architecture and the progressive establishment of Common Support Services.
    3. Strong harmonisation of systems, rules and procedures is achieved. This sees a reduction in timelines for industrialisation and deployment, and investments.
    4. Long-term deployment planning is implemented to realise actual benefits, e.g. through coordinated rationalisation of obsolete infrastructure.
2. **Local deployment** entails deployment with lighter coordination. This option has three key characteristics:
    1. While synchronisation of deployment remains key, coordination is limited with respect to where solutions are deployed. This implies that most SESAR Solutions are likely to be deployed in most locations, based on local rather than systemwide business cases.
    2. There is no common project covering the evolution of the ATM architecture.
    3. Only a moderate degree of harmonisation of systems, rules and procedures is implemented.

Regardless of the option, a positive business case for individual parties remains necessary to invest. Where the local business case is uncertain (e.g. because of a long payback period or because the benefits are to be reaped at network, rather than local level), or negative for specific categories of stakeholders, appropriate incentive mechanisms may become relevant and necessary.

In accordance with the vision (see Chapter 2), SESAR Solutions are progressively deployed in order to:

A. address known critical network performance deficiencies, notably through the implementation of the Pilot Common Project addressed (PCP);

B. deliver efficient service and infrastructure, such as the automation of routine tasks and infrastructure rationalisation (new Essential Operational Changes);

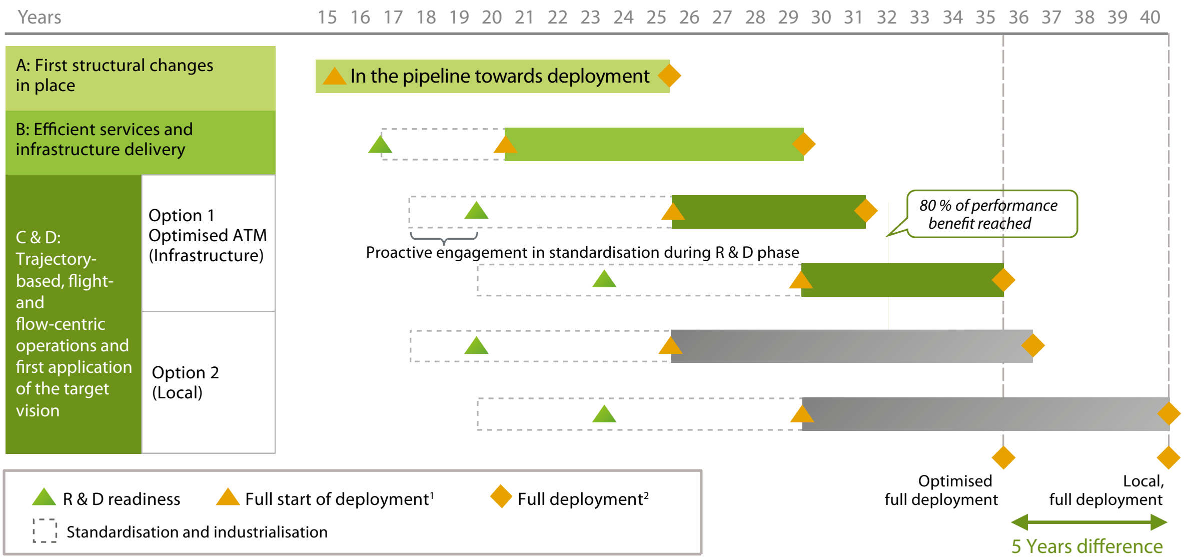
C. allow regional, trajectory-based, flight- and flow-centric operations, which require solutions such as fully integrated data communications and high efficiency regional, flight centric ATM. (SESAR 2020 wave 1);

D. achieve target vision (performance-based operations), realising the first applications of the target vision, with end-to-end flight- flow-centric operations (SESAR 2020 wave 2).

These phases are illustrated in Figure 12 . Specifically, the graph highlights the following:

- Each phase starts with research, which once completed results in SESAR Solutions that are ready for industrialisation.
- Readiness for industrialisation is reached at the end of 2016, 2020 and 2024 for deployment phases II to IV.
- It is estimated that the start of industrialisation to full deployment will take between 11 to 16 years. Full deployment implies that SESAR Solutions are rolled out so that the majority of benefits can be realised.
- Optimised deployment (option 1) enables a stronger evolution in harmonisation of systems, procedures and rules than in local deployment. Moreover, this option entails fewer locations to roll out the full set of SESAR Solutions for implementation where needed.

Figure 12 **Target roll-out of SESAR by 2035**



[1] Representing start of deployment of solutions in all operating environments, deployment can start earlier for, for example, airspace users and some ANSPs.
[2] Not all solutions deployed everywhere, e.g. only 50 % of scheduled aircrafts equipped, military aircraft taking longer to deploy.

- Proper coordination of standardisation and roll-out can shorten deployment timelines by 5 years for the last two deployment phases and would imply full deployment by 2035 for optimised deployment compared to 2040 for local deployment.

5.2 Deployment scenarios

This section shows the deployment scenarios for Essential Operational Changes, from PCP and beyond. It therefore describes scenarios for those Essential Operational Changes from SESAR 1 that are 'in the pipeline towards deployment', as described in Chapter 4. It does not give a holistic view for the deployment of the entire SESAR project.

Each deployment scenario indicates in which sub-operating environment(s) performance gains are realised and the roll-out time for each of the identified Essential Operational Changes. The scenarios also indicate the timescales for the start and end of deployment, as well as by when benefits will start and then become fully realised.

Figure 13 shows the deployment scenarios for the PCP Essential Operational Changes, while Figure 14 shows the scenarios for new Essential Operational Changes.

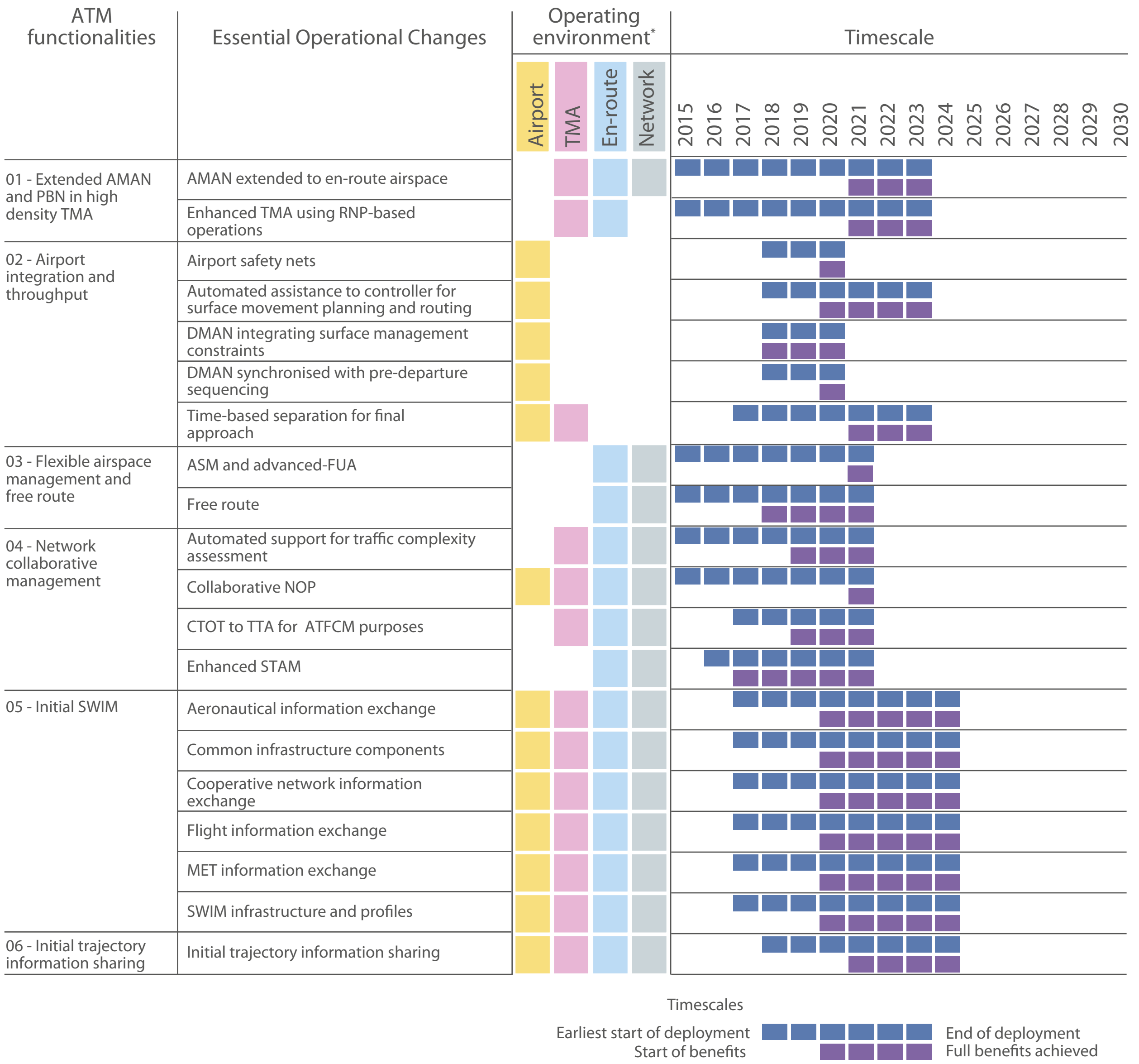
Seeing is believing: demonstrating benefits on a large scale

SESAR members and partners have conducted over 30 000 trials on commercial flights in real-life operational conditions, offering a critical mass of proof of the performance benefits that SESAR Solutions can deliver to the ATM community. These activities address all phases of the flight and key performance areas (KPAs), with a number of projects specifically focusing on how SESAR can result in significant reductions in CO_2 emissions.

Thanks to the involvement of so many actors, these demonstrations are providing a bridge towards deployment, reducing the time to market for SESAR Solutions by accelerating their readiness for industrialisation both in Europe and worldwide. Not only that, but these activities are making sure that SESAR Solutions are globally applicable and interoperable.

SUCCESS STORY

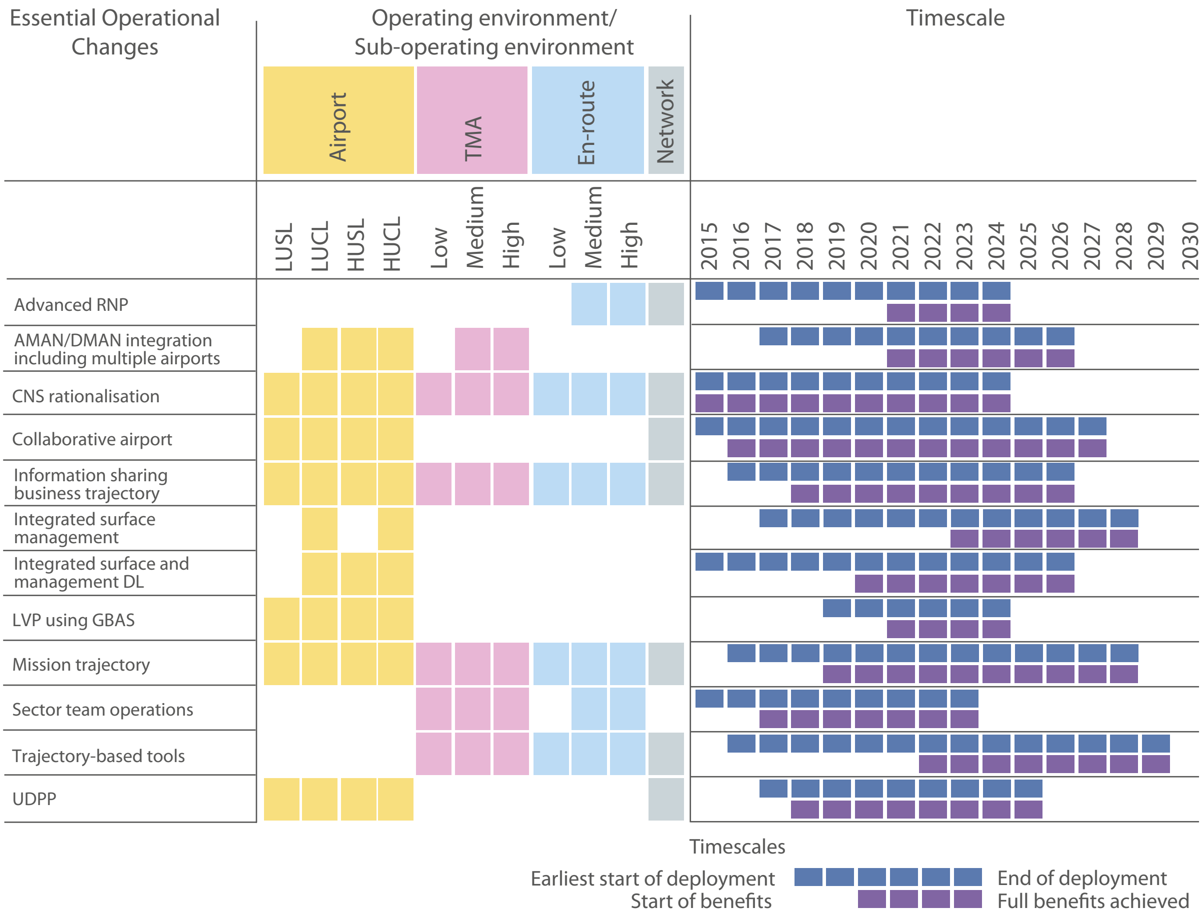
Figure 13 **PCP deployment scenarios**



* The detailed list of operating environments subject to the PCP Operational Changes is in the PCP IR (EU) 716/2014.

The end dates for the Essential Operational Changes are those from the PCP IR (EU) 716/2014. The earliest start of deployment and start of benefits dates are subject to the readiness/ availability of the ATM Technology Changes in the Essential Operational Changes.

Figure 14 **New Essential Operational Changes deployment scenarios**



Key:

Airports

- LUSL: Low utilisation (<90% utilisation during 1 or 2 peak periods a day) simple layout.
- LUCL: Low utilisation (<90% utilisation during 1 or 2 peak periods a day) complex layout
- HUSL: High utilisation airports (>90% utilisation during 3 or more peak periods a day) simple layout
- HUCL: High utilisation airports (>90% utilisation during 3 or more peak periods a day) complex layout

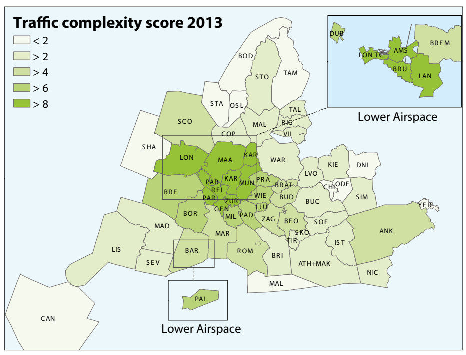
TMA

- Low complexity TMAs handle less than 30 movements in peak hour;
- Medium complexity TMAs handle between 30 and 60 movements in peak hour;
- High complexity TMAs handle more than 60 movements in peak hour.

En-route

For en-route operating environments, the categories are based on the complexity score (a composite measure combining traffic density (concentration of traffic in space and time) with structural complexity (structure of traffic flows) described in the PRR 2013 Report:

- Low complexity en-route has a complexity score of less than 2;
- Medium complexity en-route has a complexity score of between 2 and 6;
- High complexity en-route has a complexity score of more than 6.




A350 XWB

5.3 ATM Technology Changes supporting Essential Operational Changes

Each Essential Operational Change requires the implementation of ATM Technology Changes by one or more stakeholders. Section 5.4 provides roadmaps which show the ATM Technology Changes supporting the Essential Operational Changes, with reference to the dates for the initial operating capability (IOC) for the following groups of stakeholders:

- Airspace users (AUs) ([42])
  - Military
  - General aviation (GA)
  - Business aviation (BA)
  - Rotorcraft (RC)
  - Scheduled aviation
- Air navigation service providers (ANSPs)
  - Military
  - Civil
- Airport operators
  - Military
  - Civil
- Network Manager (NM)

Figure 15 identifies, at an aggregated level, both the ATM Technology Changes necessary to deliver each of the PCP Essential Operational Changes and the ATM Technology Changes necessary to deliver each of the new Essential Operational Changes. The aggregation represents a high-level grouping of individual technology changes for each stakeholder. For more details, see the European ATM portal (www.atmmasterplan.eu).

([42]) RPAS-related technology changes are not reflected as implementation is not mature.

Figure 15 **ATM Technology Changes**

Aggregated ATM Technology Changes to support Essential Operational Changes

This table identifies, at an aggregated level, the ATM Technology Changes necessary to deliver each of the Essential Operational Changes. The aggregation represents a high-level grouping of individual technology changes for each stakeholder.

Key:
- PCP (green)
- New Essential Operational Changes (blue)

Key Features	Optimised ATM network services							Advanced air traffic services					
	Airspace management and advanced flexible use of airspace	Automated support for traffic complexity assessment	Collaborative NOP*	CTOT to TTA for ATFCM	Enhanced short-term ATFCM measures	Free route	User-driven prioritisation process (UDPP)	AMAN extended to en-route airspace	Enhanced terminal airspace using RNP-based operations	Advanced RNP	AMAN/DMAN integration including multiple airports	Sector team operations	Trajectory-based tools
ANSP													
Aeronautical/meteorological information data sharing	PCP	PCP	PCP	PCP	PCP	PCP				New			
Airport ATC tools													
Airport vehicle systems													
Airport-CDM							New						
Airspace management system	PCP					PCP							
AMAN/DMAN								PCP			New		
Complexity management tools		PCP				PCP							New
Datalink systems and services													
Demand and capacity balancing		PCP	PCP	PCP	PCP	PCP							
Enhanced conflict management tool						PCP			PCP	New			New
Enhanced CWP	PCP					PCP					New	New	New
Enhanced FDP						PCP		PCP			New	New	New
Flight object implementation		PCP		PCP		PCP							
Flight planning and demand data						PCP							
Ground communications and information infrastructure	PCP	PCP	PCP	PCP	PCP	PCP							
Navigation infrastructure									PCP	New			
Safety net tools									PCP	New			New
Surface management													
Surveillance infrastructure													New
Airport operator													
Aeronautical/meteorological information data sharing	PCP	PCP	PCP	PCP	PCP	PCP							
Airport planning support			PCP										
Airport vehicle systems													
Airport-CDM							New						
AMAN/DMAN											New		
Demand and capacity balancing			PCP		PCP								
Enhanced CWP											New		
Ground communications and information infrastructure	PCP	PCP	PCP	PCP	PCP	PCP							
Surface management													
Surveillance infrastructure													
Airspace user													
ADS-B OUT Capability													New
Aeronautical/meteorological information data sharing	PCP	PCP	PCP	PCP	PCP	PCP							
Airport-CDM													
Datalink systems and services													
Demand and capacity balancing			PCP		PCP		New						
Enhanced FOC/WOC Systems	PCP		PCP			PCP	New						
FMS capability to support i4D operations													
FMS capability to support mission trajectory													
FMS upgrade for advanced RNP						PCP			PCP	New			
Ground communications and information infrastructure	PCP	PCP	PCP	PCP	PCP	PCP							
Initial GBAS Cat II/III using GPS L1													
Manual/D-TAXI													
On-board situational awareness and alerts on the ground													
Network Manager													
Aeronautical/meteorological information data sharing	PCP	PCP	PCP	PCP	PCP	PCP				New			
Airport-CDM													
Airspace management system	PCP					PCP							
Demand and capacity balancing	PCP	PCP	PCP	PCP	PCP	PCP	New						
Enhanced FOC/WOC Systems													
Flight object implementation						PCP							
Flight planning and demand data	PCP		PCP	PCP		PCP							
Ground communications and information infrastructure	PCP	PCP	PCP	PCP	PCP	PCP							

*includes AOP

Aggregated ATM Technology Changes to support Essential Operational Changes

This table identifies, at an aggregated level, the ATM Technology Changes necessary to deliver each of the Essential Operational Changes. The aggregation represents a high-level grouping of individual technology changes for each stakeholder.

Key:
- PCP (green)
- New Essential Operational Changes (blue)

Key Features	High-performing airport operations									Enabling aviation infrastructure									
	Airport safety nets	Automated assistance to controller for Surface Movement Planning and Routing	DMAN integrating surface management constraints	DMAN synchronised with pre-departure sequencing	Time-based separation for final approach	Collaborative airport	Integrated surface management	Integrated surface management DL	LVP using GBAS	Aeronautical information exchange	Common infrastructure components	Cooperative network information exchange	Flight information exchange	Initial trajectory information sharing (i4D)	Meteorological information exchange	SWIM technical infrastructure and profiles	CNS rationalisation	Information sharing and business trajectory	Mission trajectory
ANSP																			
Aeronautical/meteorological information data sharing						New				PCP	PCP	PCP	PCP		PCP	PCP		New	New
Airport ATC tools	PCP	PCP	PCP		PCP		New												
Airport vehicle systems								New											
Airport-CDM						New													
Airspace management system																			
AMAN/DMAN			PCP	PCP															
Complexity management tools																			
Datalink systems and services								New						PCP				New	
Demand and capacity balancing			PCP			New													
Enhanced conflict management tool																			
Enhanced CWP	PCP	PCP	PCP	PCP	PCP	New	New	New						PCP				New	
Enhanced FDP																		New	New
Flight object implementation										PCP	PCP	PCP	PCP		PCP	PCP		New	
Flight planning and demand data																		New	New
Ground communications and information infrastructure						New	New			PCP	PCP	PCP	PCP	PCP	PCP	PCP	New	New	New
Navigation infrastructure									New								New		
Safety net tools	PCP				PCP		New												
Surface management	PCP	PCP	PCP			New	New	New											
Surveillance infrastructure							New										New		
Airport operator																			
Aeronautical/meteorological information data sharing						New				PCP	PCP	PCP	PCP		PCP	PCP			New
Airport planning support						New													
Airport vehicle systems							New	New											
Airport-CDM						New													
AMAN/DMAN			PCP	PCP															
Demand and capacity balancing						New													
Enhanced CWP																			
Ground communications and information infrastructure						New	New	New		PCP	PCP	PCP	PCP		PCP	PCP		New	New
Surface management		PCP		PCP		New	New	New											
Surveillance infrastructure																	New		
Airspace user																			
ADS-B OUT Capability																			
Aeronautical/meteorological information data sharing						New				PCP	PCP	PCP	PCP		PCP	PCP			New
Airport-CDM						New													
Datalink systems and services								New						PCP					
Demand and capacity balancing						New													
Enhanced FOC/WOC Systems														PCP				New	New
FMS capability to support i4D operations														PCP					
FMS capability to support mission trajectory																			New
FMS upgrade for advanced RNP																			
Ground communications and information infrastructure						New				PCP	PCP	PCP	PCP		PCP	PCP		New	New
Initial GBAS Cat II/III using GPS L1									New										
Manual/D-TAXI								New											
On-board situational awareness and alerts on the ground								New											
Network Manager																			
Aeronautical/meteorological information data sharing						New				PCP	PCP	PCP	PCP		PCP	PCP		New	New
Airport-CDM						New													
Airspace management system																			New
Demand and capacity balancing						New													
Enhanced FOC/WOC Systems																			New
Flight object implementation														PCP				New	
Flight planning and demand data																		New	New
Ground communications and information infrastructure						New				PCP	PCP	PCP	PCP		PCP	PCP		New	New

5.4 Deployment roadmaps for each stakeholder

The ATM Technology Changes necessary to deliver the Essential Operational Changes have been aggregated into high-level groupings of individual technical system changes for each stakeholder.

Enabling stakeholders to achieve performance benefits may require synchronised implementation of ATM Technology Changes across different domains (e.g. air and ground). Synchronising deployment planning between different stakeholders will avoid cases where investments made by one stakeholder cannot deliver benefits because other stakeholders have not yet made the corresponding changes required. The stakeholder roadmaps provide dates for the first technical availability. Additional elements such as investment cycles and the 'capability to deploy' need to be taken into account when considering implementation.

The triangles in the roadmaps represent technology changes that are necessary to support the Essential Operational Changes but have already been deployed. The ATM Technology Changes relating to the PCP are identified on the roadmaps by a grey background.

Section 5.4.1 presents the AU roadmap, divided into scheduled, GA and BA, rotorcraft and military airspace users (military transport aircraft). This roadmap also includes the flight and wing operations centres (FOC/WOC).

Section 5.4.2 presents the ANSP roadmap, divided into civil and military ANSPs.

Section 5.4.3 presents the airport operator roadmap, divided into civil and military airport operators.

Section 5.4.4 presents the NM roadmap.

Section 5.5 presents the communication, navigation and surveillance (CNS) roadmaps.

5.4.1 Airspace user roadmap

The airspace user roadmap groups a number of related ATM Technology Changes under a single heading. The individual changes that make up the detail of these groups may have different timelines for availability. The overall timeline provided for each group is therefore based on the individual change that will be the last to become available. Further avionics ATM Technology Changes are shown in Annex B.

Figure 16 **Airspace user roadmap**

Airspace user ATM Technology Changes		Year												
			2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
Aeronautical/meteorological information data sharing	BA fixed wing								■	■				
	FOC						■	■	■	■				
	GA								■	■				
	Military								■	■				
	Scheduled								■	■				
	WOC							■	■	■				
Datalink systems and services	BA fixed wing					■								
	Military									■				
	Rotorcraft							■						
	Scheduled					■								
Demand and capacity balancing	FOC						■							
Enhanced FOC/WOC systems	FOC	◄	■	■	■	■	■	■	■					
	WOC	◄	■	■	■	■	■	■	■					
FMS capability to support i4D operations	BA fixed wing					■								
	Military									■				
	Rotorcraft							■						
	Scheduled					■								
FMS upgrade for advanced RNP	GA													
	Military											■		
	Scheduled	◄												
Ground communications and information infrastructure	FOC						■							
	WOC						■	■						
ADS-B OUT capability	BA fixed wing	◄												
	GA													
	Military		■											
	Rotorcraft	◄												
	Scheduled		■											
Aeronautical/meteorological information data sharing	BA fixed wing								■					
	FOC						■	■	■	■				
	GA								■					
	Military								■	■				
	Scheduled								■	■				
	WOC							■	■	■				
Airport-CDM	FOC										■			
Datalink systems and services	BA fixed wing					■								
	Military									■				
	Rotorcraft							■						
	Scheduled					■								
Demand and capacity balancing	FOC				■	■	■	■	■					
Enhanced FOC/WOC systems	FOC				■	■								
	WOC					■								
FMS capability to support mission trajectory	Military											■		

Airspace user ATM Technology Changes		Year												
			2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
FMS upgrade for advanced RNP	BA fixed wing	◀												
	GA													
	Military											■		
	Scheduled	◀												
Ground communications and information infrastructure	FOC	◀	■	■	■	■	■							
	WOC	◀	■	■	■	■	■	■						
Initial GBAS Cat II/III using GPS L1	BA fixed wing				■									
	Military													
	Scheduled				■									
Manual/D-TAXI	BA fixed wing					■								
	GA								■					
	Military						■							
	Rotorcraft							■						
	Scheduled						■							
On-board situational awareness and alerts on the ground	BA fixed wing	◀												
	GA													
	Military	◀												
	Rotorcraft							■						
	Scheduled	◀												

Key:
- ATM Technology Changes
- ATM Technology Changes — Grey background indicates PCP
- Indicates ATM Technology Changes initially deployed before 2015

5.4.2 Air navigation service provider roadmap

Figure 17 **ANSP roadmap**

Air navigation service provider ATM Technology Changes		Year												
			2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
Aeronautical/meteorological information data sharing	Civil	◄	■	■	■	■	■	■	■	■				
	Military							■	■	■				
Airport ATC tools	Civil							■	■					
	Military										■			
Airspace management system	Civil					■	■	■						
	Military								■					
AMAN/DMAN	Civil							■						
Complexity management tools	Civil		■											
Datalink systems and services	Civil								■					
	Military								■					
Demand and capacity balancing	Civil						■							
Enhanced conflict management tool	Civil							■	■					
Enhanced CWP	Civil							■	■					
	Military								■	■	■			
Enhanced FDP	Civil		■	■	■	■	■	■	■					
Flight object implementation	Civil								■	■				
	Military								■	■				
Flight planning and demand data	Military													
Ground communications and information infrastructure	Civil	◄	■	■	■	■	■	■	■	■				
	Military						■	■	■	■				
Navigation infrastructure	Civil							■						
Safety net tools	Civil							■						
	Military										■			
Surface management	Civil							■	■					
Aeronautical/meteorological information data sharing	Civil	◄	■	■	■	■	■	■	■	■				
	Military	◄	■	■	■	■	■	■	■	■				
Airport ATC Tools	Civil									■				
Airport vehicle systems	Civil									■				
	Military									■				
Airport-CDM	Civil								■	■				
AMAN/DMAN	Civil					■	■	■	■	■				
Complexity management tools	Civil									■				
Datalink systems and services	Civil			■	■	■	■	■	■					
	Military						■	■	■					
Demand and capacity balancing	Civil		■	■	■	■	■	■	■					
	Military		■											
Enhanced conflict management tool	Civil								■					
Enhanced CWP	Civil			■	■	■	■	■	■	■	■	■	■	
	Military								■	■				
Enhanced FDP	Civil			■	■	■	■	■	■	■	■			
	Military										■			
Flight object implementation	Civil								■	■				
	Military								■	■				
Flight planning and demand data	Civil									■				
	Military									■				
Ground communications and information infrastructure	Civil	◄	■	■	■	■	■	■	■	■	■	■		
	Military						■	■	■	■				
Navigation infrastructure	Civil	◄	■	■	■	■	■	■						
Safety net tools	Civil							■	■					
Surface management	Civil								■	■				
Surveillance infrastructure	Civil	◄	■	■	■	■	■	■						
	Military	◄	■	■	■	■	■	■						

5.4.3 Airport operator roadmap

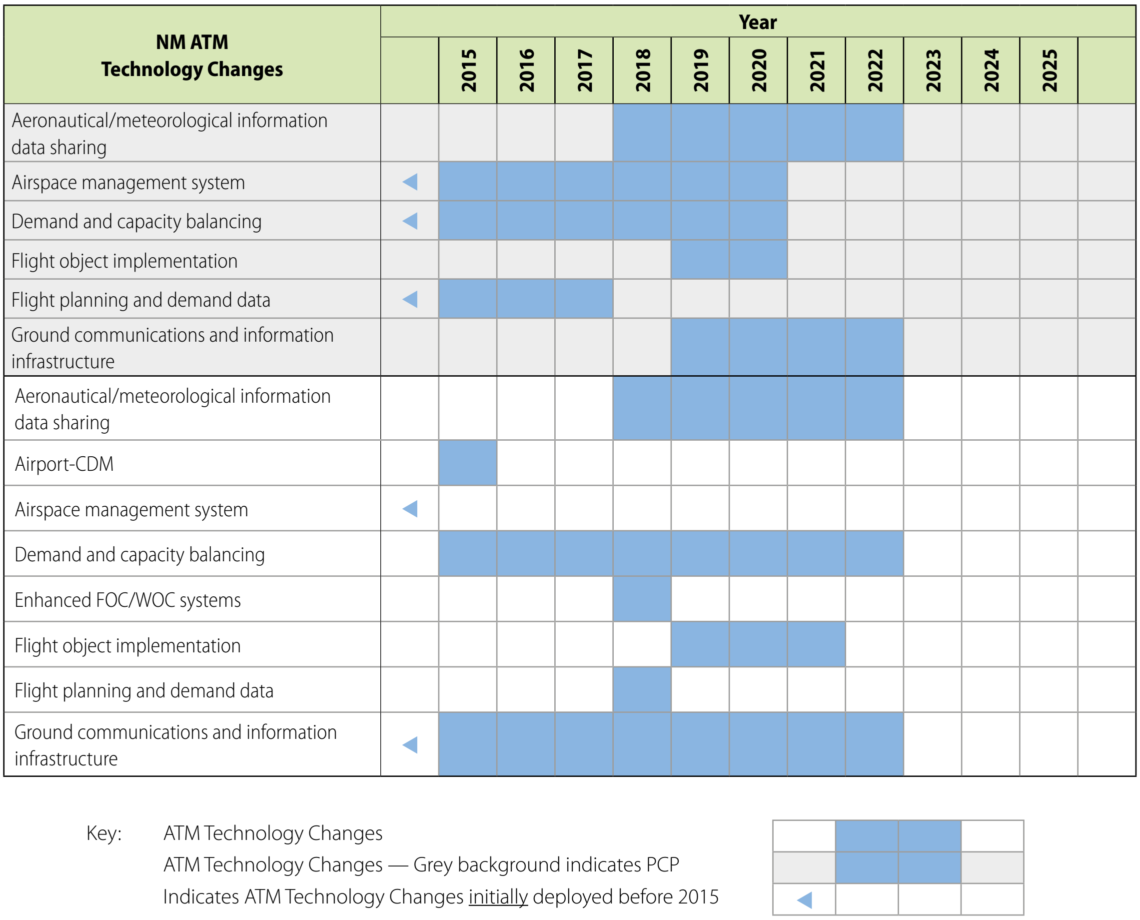
Figure 18 Airport operator roadmap

Airport operator ATM Technology Changes		Year												
			2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
Aeronautical/meteorological information data sharing	Civil							■	■	■				
	Military							■	■	■				
Airport planning support	Civil								■					
AMAN/DMAN	Civil							■						
Demand and capacity balancing	Civil						■							
Ground communications and information infrastructure	Civil						■	■	■	■				
	Military						■	■	■	■				
Surface management	Civil							■						
Aeronautical/meteorological information data sharing	Civil							■	■	■				
	Military							■	■	■				
Airport planning support	Civil				■	■	■	■	■	■	■			
Airport vehicle systems	Civil									■				
Airport-CDM	Civil	◀	■	■	■	■	■	■	■	■	■			
AMAN/DMAN	Civil							■						
Demand and capacity balancing	Civil							■	■	■				
	Military							■						
Enhanced CWP	Civil							■						
Ground communications and information infrastructure	Civil						■	■	■	■				
	Military						■	■	■	■				
Surface management	Civil									■				
	Military									■				
Surveillance infrastructure	Civil					■								
	Military					■								

Key:
ATM Technology Changes
ATM Technology Changes — Grey background indicates PCP
Indicates ATM Technology Changes initially deployed before 2015 (◀)

5.4.4 Network Manager roadmap

Figure 19 **Network Manager roadmap**



5.5 Infrastructure

CNS technologies on the ground and onboard 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 communications, navigation and surveillance domains.

In parallel, CNS systems and infrastructure for both airborne and ground 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 resulting CNS roadmaps, which provide a view of the technology and infrastructure required to support the evolving SESAR Target Concept.

5.5.1 Communications roadmap

The future communications infrastructure supporting the European ATM Network (EATMN) will contribute to a holistic 'end-to-end' approach supporting the realisation of the future ATM concept. The main trends associated with the evolution of aeronautical communications, covering ground-ground, as well as air-ground communications, are as follows:

- migration towards ground communication networks based on distributed Internet protocol technologies to enable network-centric SWIM architectures;
- deployment of aeronautical message handling systems (AMHS) to replace/enhance some segments of the ICAO aeronautical fixed telecommunications network (AFTN)/common ICAO data interchange network (CIDIN);
- continued use of air-ground voice, namely very high frequency (VHF) digital side-band (DSB) 8.33 kHz and 25 kHz, supporting critical communications, as well as the provision of ultra-high frequency (UHF) for state aircraft;
- a greater deployment of voice over internet protocol (VoIP) supporting ground communications. Digital voice for air-ground communications may be introduced in the longer term;
- widespread implementation of air-ground datalink communications which, in the future, will supplement air-ground voice (VHF) as the primary means of ATC communications;
- low-cost datalink options for GA;
- depending on studies and cost-benefit analysis, possible introduction of higher capacity datalink technologies in the context of the FCI initiatives comprising airport, terrestrial and satellite communications (SATCOM) datalink segments operating in a multilink environment. Air-air communications are also expected to be introduced and play an increasingly important role in the longer term;
- developments leading to the introduction of software defined radio (SDR) technologies

to support the airborne integration of the different datalink segments;

- the introduction of new technologies and the use of distributed IP networking technologies for both the ground and the airborne side will require as well as enable the provision of greater security capabilities addressing (cyber) security concerns and relevant threats;
- finally, in the longer term, the datalinks may also be considered for supporting exchanges of surveillance and navigation data, supporting CNS synergies and optimisation of infrastructure while maintaining the safeguards and robustness of today's segregated CNS environment.

Ground communications evolution is a decisive step towards the implementation of SWIM. This net-centric structure will then contribute to a better integration of air traffic control, airline operational control and airport systems. It will also pave the way for aircraft to become a node of SWIM.

Infrastructure changes will facilitate information exchange supporting FUA, as well as automation for ATC to ATC coordination, including the emergence of the flight object (FO) concept and advanced flight data processing systems (FDPS).

The introduction of air-ground datalink capabilities will be vital to enable real-time sharing of 4D trajectories and the availability of ATM information in the cockpit. Advanced concepts, for example new separation modes, will be enabled.

Civil-military communications interoperability will be based on interfacing between military systems and ATM-related IP structures, exchange of aeronautical information on the basis of AMHS, reliance on VoIP for ground voice exchanges, 8.33 kHz expansion (with UHF retained as gap filler), increasing datalink deployment and convergence to future communications solutions.

The communications roadmap shows the earliest deployment dates for the availability of new technologies.

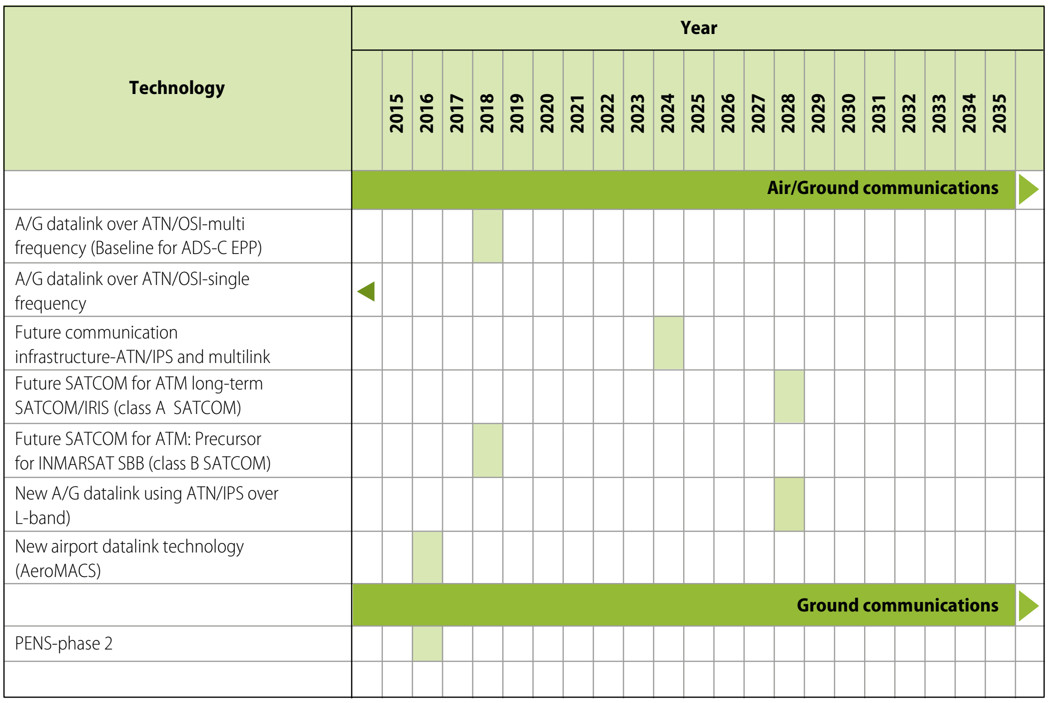
5.5.1 Navigation roadmap

The ICAO Global Air Navigation Plan (GANP) (Doc 9750) and global ATM operational concept (Doc 9854) provide the overarching framework guiding navigation evolution for civil aviation.

The main trends associated with the evolution of aeronautical navigation are:

- migration towards a performance-based approach to navigation requirements with increased reliance on satellite-based technologies (and associated multi-constellation, multi-frequency augmentation systems);

Figure 20 **Communications roadmap**



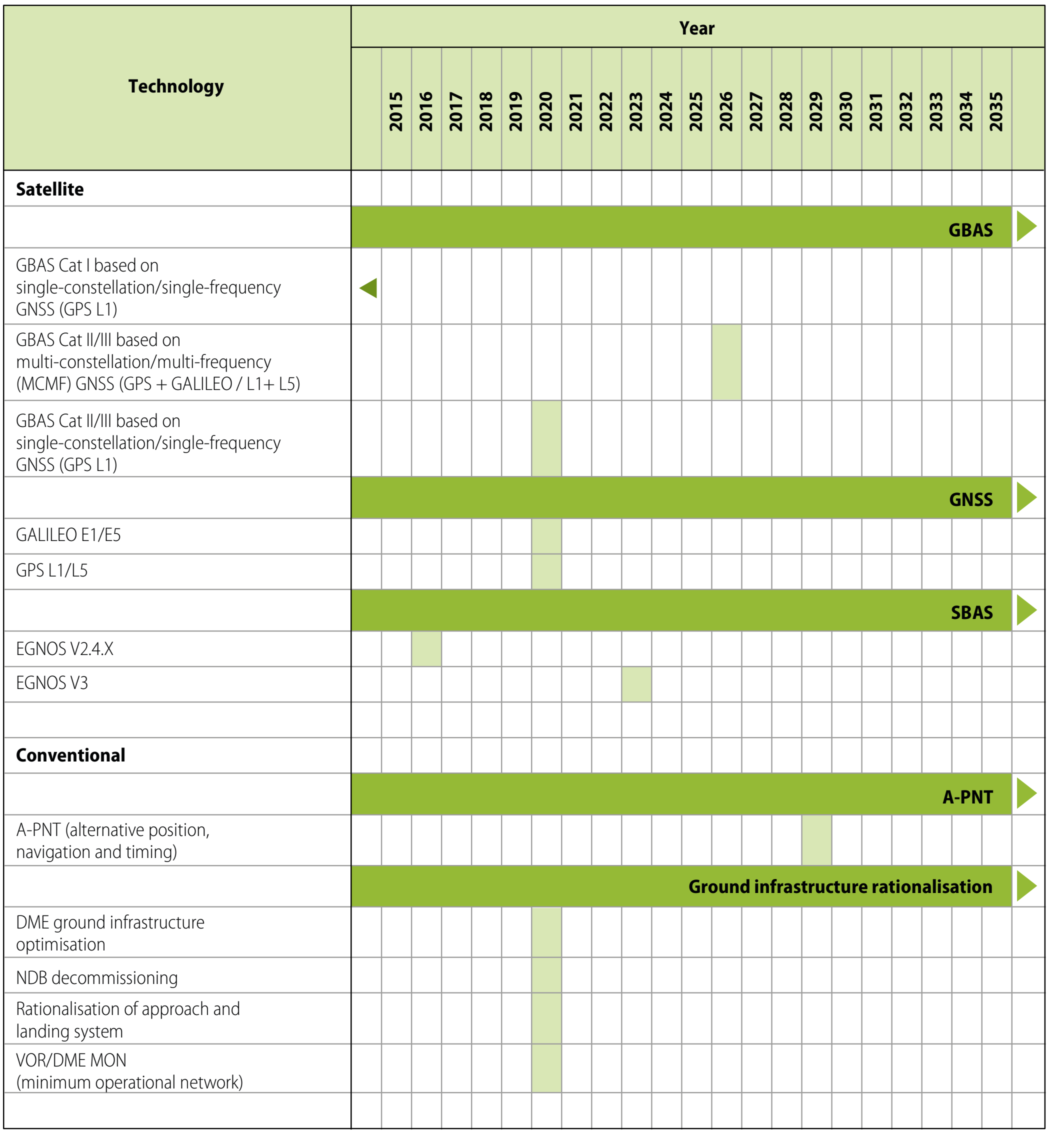
- migration towards a total RNP environment for all flight phases (based on the introduction of ICAO performance-based navigation (PBN)), as well as GBAS as an ILS replacement for precision landing including autoland;
- evolution of the navigation infrastructure to supporting multi-constellation evolutions, as well as a reversion capability providing alternatives to GNSS in terms of position, navigation and timing.

GNSS technology remains vulnerable, justifying transitional retention of ground-based terrestrial navigation aids for fall back/backup purposes. For the longer-term future, technology alternatives might have to be considered in accordance with rationalisation plans and the emergence of alternative position, navigation and timing (A-PNT).

Civil-military navigation interoperability will be based on migration to satellite-based GNSS and acceptance of performance-based equivalents. Transitional measures to accommodate lower-capability state aircraft will be required and the military must contribute to the rationalisation of navigation infrastructure. Opportunities should be offered for the military to be accommodated on the basis of performance-based equivalence re-utilising military capabilities.

The navigation roadmap shows the earliest deployment dates for the availability of new technologies.

Figure 21 **Navigation roadmap**



First GBAS Cat II/III precision landing performed

Ground-based augmentation system (GBAS) augments global navigation satellite system (GNSS) signals by sending the positioning corrections to aircraft for precision approach and landing.

Unlike the instrument landing system (ILS), GBAS is not reliant on one physical signal, but rather a digitally-coded transmission, which is loaded into the aircraft's navigation and guidance capabilities. In particular, GBAS used for Category II/III approaches (1 000 feet or less of runway visual range) offers a viable and cost-effective solution for low visibility operations, overcoming ILS operational limitations such as the critical and sensitive areas.

While GBAS CAT I approaches have been in operation in Europe for several years, in 2013, SESAR members reached a major milestone - a first CAT III approach enabled solely by GBAS. In 2014, SESAR members embarked on a round of successful validation flights, testing a CAT II/III avionics receiver prototype. The results are positive and, assuming that standardisation and regulation progress as planned, the entry into service of GBAS Cat II/III can now be expected in the 2018-2019 timeframe.

5.5.2 Surveillance roadmap

Surveillance provision comprises the availability of ground sensors and surveillance data processing and distribution systems which support 3-mile and 5-mile separation requirements. Future airborne surveillance requirements will essentially be linked with the ability to extract the avionics parameters required to support applications, normally standardised by EUROCAE/RTCA, and to broadcast and receive such information. Surveillance fusion and sharing is increasingly being developed and is used almost everywhere.

The current surveillance infrastructure is mainly composed of secondary surveillance radar (SSR), mono-pulse secondary surveillance radar (MSSR), MSSR mode-s and primary surveillance radar (PSR). Recent technological developments such as the emergence of automatic dependent surveillance-broadcast (ADS-B) and wide-area multilateration (WAM) have reached maturity and are being deployed in many parts of the world including Europe. The European surveillance infrastructure will be provided by a mix of these surveillance techniques.

In addition to ground-based surveillance, satellite-based ADS-B will become available as a source for surveillance especially in oceanic and remote areas. ADS-B will also enable the development of new airborne surveillance operational services, including air traffic situational awareness (ATSAW), and airborne separation assistance system (ASAS), such as sequencing and merging and self-separation. Future airborne applications will require changes in the avionics (ADS-B Out and ADS-B In) to process and display the air situation picture to the pilot. A low-cost ADS-B solution for GA is to be provided.

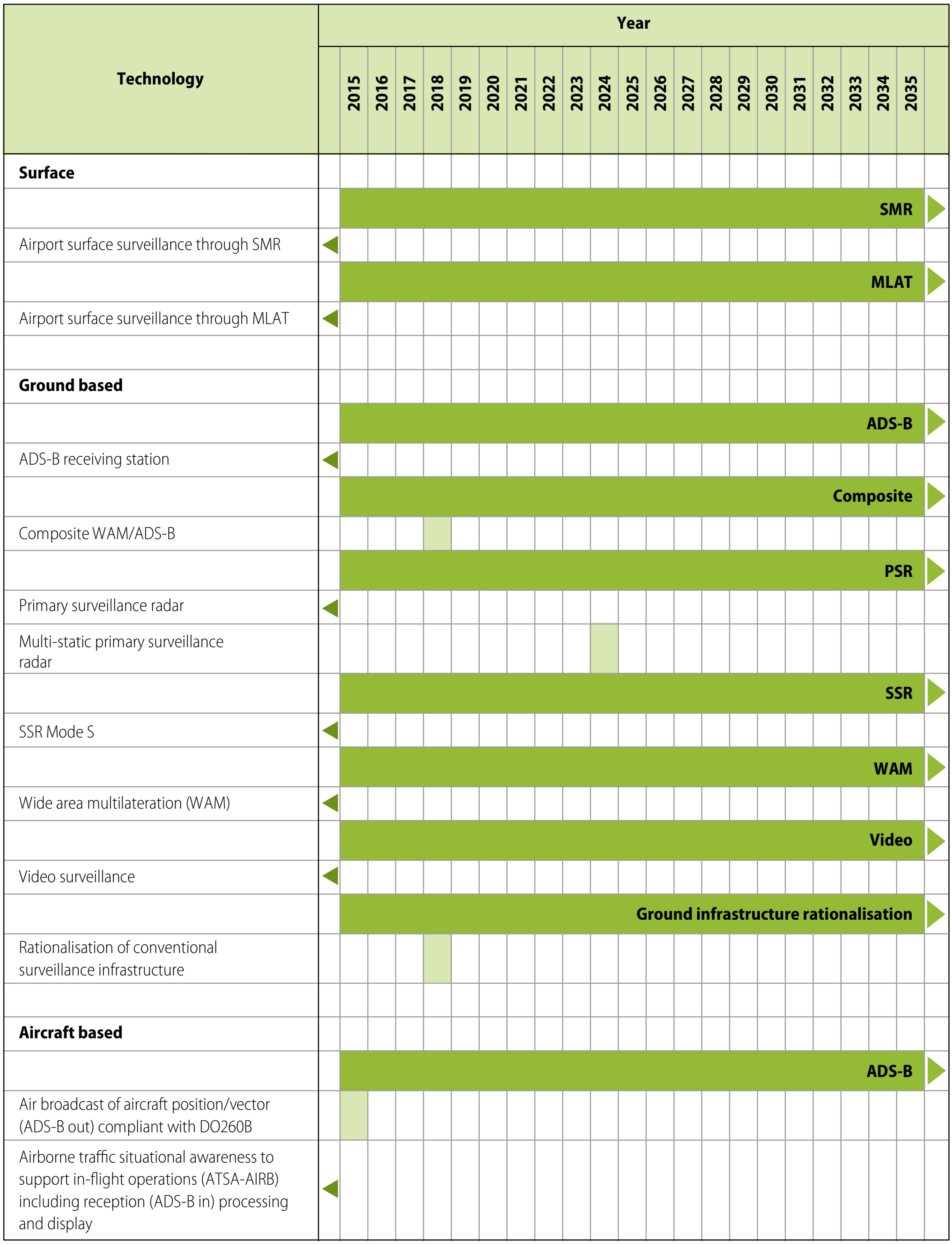
For airports, a locally-optimised mix of the available technologies, i.e. airport multilateration, surface movement radars and ADS-B, will enable advanced surface movement guidance and control systems (A-SMGCS) and integrated airport operations. This includes the availability of surveillance information on a moving map, using a human-machine interface (HMI) in the cockpit and in surface vehicles.

A rationalised (i.e. cost-efficient and spectrum-efficient) ground surveillance infrastructure can be foreseen to be gradually deployed, using the opportunities offered by new technologies. Surveillance data sharing will also contribute to reduce the number of infrastructure elements (e.g. radars) as the information (e.g. surveillance data) can be made available through ground communications networks.

The interrelation of surveillance techniques with communications and navigation will become a reality. The avionics carried on board an aircraft must become a fully integrated element of the surveillance infrastructure. The scope of surveillance systems will extend to embrace an increasingly diverse range of avionic components, such as GNSS, traffic computers and cockpit display systems, as well as transponders.

Surveillance provision is regulated in the SES implementing rules on performance and interoperability of surveillance and aircraft identification.

Figure 22 **Surveillance roadmap**



Civil-military surveillance interoperability will be based on equipage of military aircraft with Mode S and ADS-B capabilities and the retention of non-cooperative surveillance means.

The surveillance roadmap (see Figure 22) shows the earliest deployment dates for the availability of new technologies.

5.5.3 Cybersecurity

The current ATM system is a patchwork of bespoke systems and networks connected by a bewildering array of different interfaces, often utilising national and proprietary standards. It is clear that the future ATM system will rely on an increase in interconnected systems that utilise modern technologies and interoperability to deliver operational improvements through a shared view of all aeronautical information. Two key concerns that threaten these benefits are underlined:

- Increased interconnectivity and integration — both in terms of interactions between actors (ANSPs, airlines, airports, RPAS) and CNS systems — expand the attack surface and create new vulnerabilities, for example through third-party access to networks and systems.
- Interoperability implies an increased use of commercial-off-the-shelf (COTS) components and without careful planning a corresponding loss of diversity. This increases the likelihood of introducing publicly-released common vulnerabilities into the system.

In particular, the development of system-wide information management (SWIM) presents opportunities to establish the necessary IT service management principles and cybersecurity architecture at an early stage of development, before the costs of retrofitting access control, intrusion detection and forensics become prohibitive. SESAR has therefore to be seen as an opportunity to consider wider issues of industry governance and requested measures to ensure the future resilience of ATM networks and systems. Standardised interfaces for services, in particular standardised interfaces for security services, will facilitate their use, and appropriate hardened interfaces for all services and systems will reduce the potential for abuse and subversion. Thus it is essential that the development of cybersecurity is performed in parallel with the development of technical enablers.

For ATM, a number of guiding principles should be defined for the organisational and technical measures that are needed to encourage cyber resilience. These must recognise that organisations and technical systems will suffer from cyber incidents and attacks, and there is a possibility that some attacks in the future may be successful.

In consequence, overall service management, configuration and change management, access management, intrusion detection, forensic and emergency response capabilities are needed and resilience engineering requires the following six mechanisms: prevision, prevention, protection, recognition, response, and recovery (P3R3).

One area of particular concern is the identification and development of standardisation activities and systems. Systems should be developed and built using best practice. Common access to shared networks and resources requires common standards and associated guidelines, covering the full range of cybersecurity considerations. It also includes defining technical and engineering rules applicable across a broad range of stakeholders.

A key issue for ATM will be how to leverage well-established cybersecurity standards while ensuring they are ATM relevant. Accordingly, existing safety and security standards may need to be tailored or have a profile developed for ATM.

It has to be recognised that cyber threats are not static; they evolve with the sophistication of attackers and as systems change new vulnerabilities are introduced. Crucially, cybersecurity is not just about technical IT solutions; equally physical, human, process and (pan-) organisational measures are needed. Cyber protection in this context will require every ATM stakeholder to prepare and protect itself to be ready to detect and analyse attacks as early as possible, and respond effectively to avoid their escalation.

It is also essential to address the requirements for cross-border collaboration, as well as sharing of information about cyber threats and vulnerabilities. The governance model will also have to consider the appropriate cross-border and cross-sector responses when the whole integrity and operational efficiency of the European ATM system is threatened. Finally, the commitment of people to protecting their organisations is an essential component of a strong cyber protection. This means a critical part of the cybersecurity programme must be to focus on the human aspects of the organisation and all stakeholders.

While cybersecurity is crucial to ATM, it has to be integrated consistently with aviation security as a whole. Furthermore, cybersecurity is inherently a cross-sector domain and hence aviation cybersecurity should be linked to the broader national and European cybersecurity institutional and regulatory frameworks ([43]). Though mainly focusing on SWIM, its scope has to be extended to all necessary ATM technological enablers (e.g. GNSS).

([43]) Including the 'Policy on Critical Information Infrastructure Protection' (CIIP) and the 'Communication on a cybersecurity strategy of the European Union — An open, safe and secure cyberspace'.

5.5.1 Spectrum

To provide a safe and efficient global transportation service, aviation requires internationally harmonised radio spectrum allocations. CNS cannot operate without an adequate radio spectrum. There is a growing need to identify a suitable spectrum for new aviation applications, such as wireless avionics intra-communications systems, global flight tracking, and the future deployment of RPAS into non-segregated airspace. In addition, the available spectrum needs to sustain future aviation growth. In anticipation of the expected air traffic growth and the progressive introduction of new vehicles and systems, the SESAR Aeronautical Spectrum Strategy sets the basis for European aviation spectrum policy, addressing medium- and long-term spectrum availability.

The overall aim of the strategy is: 'To secure the long-term availability of suitable radio spectrum to meet all of aviation's future objectives through cooperative engagement in the global spectrum environment'. Therefore, the key issues are:

- The availability of a suitable interference-free radio spectrum is an essential enabler for CNS systems used to support aviation safety and efficiency.
- New spectrum bands for aviation use are unlikely to be made available. Therefore, aeronautical spectrum allocations will continue to be under significant pressure from other sectors for the foreseeable future.
- There is a permanent need for improved civil-military spectrum coordination to secure wider aviation interests.
- A long-term vision is needed of how aviation spectrum management should be conducted in Europe.
- Spectrum needs to be included as a fundamental component within aviation's strategic programmes.
- Harmonised European aeronautical spectrum policies are needed to fulfil the requirements of the SESAR deployment plan and meet the needs of all airspace users, including military and general aviation.

The aim is to ensure that spectrum supportability issues are included within CNS development programmes for ATM stakeholders through the following actions:

- ensuring sufficient and suitable spectrum availability for CNS systems;
- minimising the likelihood of incompatibility;
- ensuring there are no in-service interferences;
- assessing the operational impact on other aeronautical systems;
- making appropriate spectrum provisions through International Telecommunication Union (ITU) processes;
- ensuring the collation of evidence-based data at appropriate stages of project development and, following validation, developing an appropriate action plan to secure spectrum supportability;
- ensuring cohesion and coordination between spectrum management and the overall CNS strategy.

It is imperative to ensure existing spectrum requirements are protected from interference by other users in adjacent areas of spectrum. Figure 23 identifies the current frequency requirements for which there is potential for interference, together with new allocations.

5.6 Standardisation and regulatory view

Building an efficient, sustainable and safe Single European Sky (SES), requires the modernisation of the European ATM system. This modernisation should be enabled by the envisaged evolution of the global and European regulatory frameworks to rely increasingly on performance-based, less prescriptive, regulation with the technical details and means of compliance at the level of voluntary standards.

To deploy the required ATM-related functionalities and to build the European ATM system stemming from SESAR development, there is an increased need for new standards and appropriate regulations. The European regulatory and standardisation framework has to be able to capture and address those demands to ensure that the necessary provisions are available in a timely fashion.

Beyond the regulatory context, there exists a significant need for standards to support the harmonised implementation of concepts and technologies arising directly from industry. There are many examples of standards-led deployments in progress, without awaiting regulation, due to the clear benefits identified by the stakeholders.

Whenever regulations and standards are necessary to ensure a coordinated or harmonised deployment of the ATM-related functionalities, an early identification of those needs is important. This will allow standardisation and regulatory organisations to plan sufficiently in advance and deliver on time, and avoid development times needed to produce the appropriate regulatory material and industry standards to affect the start of deployment of those functionalities.

Figure 23 Current frequency requirements

Current frequencies adjacent to those considered for allocation to other users		Systems/Service
24.25 - 24.65	GHZ	Airport surface detection systems (regions 2 and 3)
15.4 - 15.7	GHz	Airport surface detection equipment/airborne weather radar.
13.25 - 13.4	GHz	Doppler navigation aids
3.4 - 4.2	GHz	Very small aperture terminals (VSATS)
1.5/1.6	GHZ	Aeronautical mobile satellite communications systems
9000 - 9200	MHz	Aeronautical radar system (ground and airborne)
8750 - 8850	MHz	Doppler navigation systems
5850 - 6425	MHz	Fixed satellite service (FSS) systems used for aeronautical purposes
5350 - 5470	MHz	Airborne weather radar
5000 - 5250	MHz	Microwave landing system (MLS)
5000 - 5150	MHz	UAS terrestrial and UAS satellite communications (under consideration)
5091 - 5150	MHz	AeroMACS
5091 - 5150	MHz	Aeronautical telemetry
3400 - 4200 4500 - 4800	MHz MHz	Fixed satellite service (FSS) systems used for aeronautical purposes
4200 - 4400	MHz	Radio altimeters
2700 - 3100	MHz	Approach primary radar
1159 - 1610	MHz	Global navigation satellite systems (GNSS)
1215 - 1350	MHz	Primary radar
960 - 1164	MHz	Aeronautical communications future communication system
1030 & 1090	MHz	Secondary surveillance radar 1090 extended squitter Multilateration (MLAT) Airborne collision avoidance system (ACAS)
960 - 1215	MHz	Distance measuring equipment (DME)
406 - 406.1	MHz	Emergency locator transmitter
5250 - 5450	kHz	Aeronautical mobile (route) service
New allocations		
77.5 - 78	GHz	Radiolocation service (could be used on advisory basis for taxiing aircraft)
4200 - 4400	MHz	Wireless avionics intra-communications (WAIC) systems
1090	MHz	Earth to space direction only for satellite reception of existing aircraft ADS-B signals to address evolving GFT applications. Future conference (WRC-19) to address evolving GFT requirements

5.6.1 Harmonisation and synchronisation

For the purposes of this section, the term 'harmonisation' refers to the process of creating a consistent and converging framework of common rules, specifications and procedures for the deployment of the changes envisaged in the Master Plan. When used in this section, 'harmonisation' is achieved through standardisation (EUROCAE, European Standardisation Organisations, EUROCONTROL and Military Organisations) and regulatory means (EASA or EC).

This section does not specifically concern the EU and FAA harmonisation issues or initiatives that are addressed in Chapter 4 (see Section 4.6.1).

The synchronisation of the deployment of Essential Operational Changes is expected to be accomplished by EC regulations and supported by incentives. The term 'synchronisation' is therefore used with the same meaning as in Commission Implementing Regulation (EU) No 409/2013 on the definition of common projects.

The requirement for future synchronised deployment is not explicitly addressed in the identified needs, which focus on the harmonisation aspects. Instead, the need for synchronisation and financial incentives mechanisms are discussed in the Business View in Chapter 6 (see Section 6.3).

5.6.2 Identifying the needs

A systematic review of each ATM Technology Change and its underlying system enablers was conducted in order to identify the standardisation and regulatory needs based on the requirement to support harmonised deployment.

In this review, the potential need for standards was assessed against the perceived need to harmonise in support of interoperability, performance, roles and responsibilities, and to create a level playing field in the aviation market as follows:

- Technical and operational changes that involve physical interfaces, or the exchange of messages, between different systems or constituents, operating in different stakeholder frameworks, may require harmonising standards to ensure interoperability.
- The introduction of changes at stakeholder level or across stakeholders may require common operating rules and procedures.
- There may be a need for standards to support the allocation of specific performance requirements to different systems and constituents within and between stakeholder frameworks.
- ATM Technology Changes may need to be subject to harmonisation in order to ensure that monopolistic positions are not created and that new entrants to the aviation market are not prevented from offering systems/constituents related to the change.

Other possible objectives of harmonisation, identified in the EASA basic regulation, are associated with the need to ensure safety, the free movement of goods, persons and services, and to achieve cost-efficient regulation and certification at a European level.

5.6.3 Standardisation and regulatory needs

This section provides a high-level view of the identified standardisation and regulatory needs currently envisaged in support of SESAR developments. It is important to acknowledge that such needs are those identified at the moment of adopting this version of the Master Plan. The proposed Essential Operational Changes are still subject to validation and consequently potential revision during the R & D phase, which may have an impact on standardisation and regulatory needs. For this reason, the detailed view of the standardisation and regulatory needs, including, where available, the responsible organisation and a fuller description of the activity is maintained on a yearly basis at Level 2 of the Master Plan, on the European ATM portal (www.atmmasterplan.eu).

The timely availability of mature European standards and 'soft laws' taking into account society's needs and public interests are essential to allow the harmonised deployment of interconnectible, interoperable and cost-effective solutions.

Figure 24 summarises harmonisation needs for each Essential Operational Change (PCP and new) and for each aggregated ATM Technology Change. It indicates (with a filled cell) when a new standardisation (or regulatory) activity is required to enable the harmonised deployment of this ATM Technology Change in support of the corresponding Essential Operational Change. The analysis of those systems that are impacted by an operational change can be further used to determine whether an update of an existing standard can suffice or there is a need to develop new standards. Regulatory needs will further depend on the set of standards identified and the full definition of the concept and the validation results that are produced within SESAR. Full traceability to individual activities, linked system enablers and operational improvements are provided at Level 2 of the Master Plan.

5.6.4 Contributing to the European standardisation framework

Resources are increasingly constrained so there is a pressing need to enhance the efficiency of the development of relevant standardisation activities in Europe. In light of this, and notably in recognition of the need to support SESAR deployment, the EC, EASA, EUROCAE, CEN/CENELEC/ETSI, the SJU and EUROCONTROL have come together to address how they can put into effect enhanced cooperation and coordination to ensure the effective use of available resources within ATM-related European standardisation development organisations. The parties involved in the planning and development of ATM-related standards have therefore agreed to establish the European ATM Standards Coordination Group (EASCG).

The EASCG is a joint coordination and advisory group established to coordinate the ATM-related standardisation activities, essentially stemming from the Master Plan, in support of SES implementation. The EASCG coordinates, monitors and maintains an overarching European ATM standardisation-rolling development plan, based on the latest developments from the SESAR framework, and inputs from the EASCG members, and where needed other key actors in the aviation domain. These tasks notably include maintenance and updates of the PCP 'Indicative roadmap with respect to standardisation and regulation'.

The European ATM standardisation rolling development plan will eventually feed back into the plans and work programmes of EUROCAE, CEN/CENELEC/ETSI, EUROCONTROL and other standard-making organisations, subject to approval by their respective governing bodies.

The SDM and EDA participate as observers within the EASCG. EDA participate in order to maintain visibility and exchange information on the specific standardisation needs of military stakeholders, applicability of civil standards to military projects and to ensure that future standards having a civil-military nature address specific requirements supporting civil-military interoperability.

The EASA Rulemaking Programme concerning support to the implementation of the Master Plan will be developed using the preliminary impact assessment methodology. This process will identify the regulatory drivers based on safety/environment, level playing field, efficiency/proportionality and the importance of the task.

5.6.5 Global standardisation

A proposal has been put forward for the development of an ICAO standardisation roadmap to complement the ICAO work programme. The scope for this proposed roadmap is not limited to GANP and Global Aviation Safety Plan (GASP), but covers all activities which are the responsibility of the ICAO Air Navigation Bureau (ANB) and the Air Navigation Commission (ANC). This is part of a wider response to the need for a performance-based approach to ICAO provisions, which recognises standard-making organisations (SMOs) as providers of supporting technical specifications. Discussions are being held regarding the use of standards round table meetings as a mechanism to discuss and exchange information with the major stakeholders and SMOs. In doing so, this forum would allow, from a planning perspective, SMOs to align their respective roadmaps or work programmes with ICAO for the development of standards and technical specifications to support ICAO in validating and referencing SMO technical specifications.

Discussions are underway on how to coordinate and harmonise the Master Plan standardisation roadmap with the ICAO standardisation roadmap in the context of the 2016 and 2019 GANP updates. All relevant European SMOs are active in the newly established EASCG, where the coordination and evolution of the European standardisation activities will take place.

Figure 24 New standardisation and regulatory needs

Aggregated ATM Technology Changes	Essential Operational Changes																			
	PCP																			
	Aeronautical information exchange	Airport safety nets	AMAN extended to en-route airspace	Airspace management and advanced flexible use of airspace	Automated assistance to controller for surface movement planning and routing	Automated support for traffic complexity assessment	Collaborative NOP *	Common infrastructure components	Cooperative network information exchange	CTOT to TTA for ATFCM	DMAN integrating surface management constraints	DMAN synchronised with pre-departure sequencing	Enhanced short-term ATFCM measures	Enhanced terminal airspace using RNP-based operations	Flight information exchange	Free route	Initial trajectory information sharing (i4D)	Meteorological information exchange	SWIM technical infrastructure and profiles	Time-based separation for final approach
ADS-B OUT capability																				
Aeronautical/Meteorological information data sharing	○●			○●		○	○	○●	○●	○			○		○●	○		○●	○●	
Airport ATC tools																				○●
Airport planning support																				
Airport vehicle systems																				
Airport-CDM												○●								
Airspace management system																				
AMAN/DMAN											○●	○●								
Complexity management tools																				
Datalink systems and services																	○●			
Demand and capacity balancing											○●									
Enhanced conflict management tool														●		●				
Enhanced CWP		○●			○●						○●						●			
Enhanced FOC/WOC systems				○●			○●									○	○			
Flight object implementation and enhanced FDP	○					○		○	○	○					○●	○●	○	○	○	
Flight planning and demand data							●			○						○	○			
FMS capability to support i4D operations																	○●			
FMS capability to support mission trajectory																				
FMS upgrade for advanced RNP														○●		○●				
Ground communications and information infrastructure	●							●	●						●	○	●	○●	●	
Initial GBAS Cat II/III using GPS L1																				
Manual / D-TAXI																				
Navigation infrastructure														○						
On-board situational awareness and alerts on the ground																				
Safety net tools														●		○●				
Surface management		○●			○						○●									
Surveillance infrastructure																				

Aggregated ATM Technology Changes	Advanced RNP	AMAN/DMAN integration including multiple airports	CNS rationalisation	Collaborative Airport	Information sharing and business trajectory	Integrated surface management	Integrated surface management DL	LVPs using GBAS	Mission trajectory	Sector based operations	Trajectory-based tools	User-driven prioritisation process (UDPP)
	Essential Operational Changes – New Essential Operational Changes											
ADS-B OUT capability											○●	
Aeronautical/Meteorological information data sharing	○●			○●					○●			
Airport ATC tools						○●						
Airport planning support				○●								
Airport vehicle systems						●	○●					
Airport-CDM				○●								
Airspace management system									○			
AMAN/DMAN		○●										
Complexity management tools											○	
Datalink systems and services					●		○●					
Demand and capacity balancing				●								●
Enhanced conflict management tool	●										●	
Enhanced CWP		○●			●	○●	○●					
Enhanced FOC/WOC systems									○●			●
Flight object implementation and enhanced FDP					○●				●			
Flight planning and demand data												
FMS capability to support i4D operations												
FMS capability to support mission trajectory									●			
FMS upgrade for advanced RNP	○●											
Ground communications and information infrastructure			●			○●	●					
Initial GBAS Cat II/III using GPS L1								○●				
Manual / D-TAXI							○●					
Navigation infrastructure			●					○				
On-board situational awareness and alerts on the ground							○●					
Safety net tools	●					○●						
Surface management				●		○●	○●					
Surveillance infrastructure			●			●					○●	

* includes AOP

Key:
- ○ Standards PCP
- ○ Standards New Essential Operational Changes
- ● Regulatory material (incl. CS/AMC)-PCP
- ● Regulatory material New Essential Operational Changes

6 Business View

6 Business View: Costs and Benefits

This chapter provides a holistic view of the monetised benefits and investment levels. Section 6.1 provides an overall view of the SESAR project, from 2015 till 2035, while Section 6.2 provides a preliminary view for the next wave of deployment (i.e. covering the new Essential Operational Changes). The Business View offers a strategic view which does not replace the need for local CBAs; it also acknowledges the diversity of local situations and investment capacities. Finally, Section 6.3 identifies the options for incentives which are important to support the deployment of SESAR as envisaged in the Master Plan.

6.1 Holistic view of SESAR benefits ambition and investment needs

The realisation of the vision (see Chapter 2) will not only bring significant direct and quantifiable performance gains to ATM and aviation, it will also mean benefits for the EU economy and society in general, as illustrated in Figure 25. Achieving these benefits will require the harnessing of SESAR capabilities, as well as other enablers for change such as the regulatory framework and ATM architecture.

Figure 25 **Delivering expected benefits**

Direct and quantifiable benefits for European ATM and aviation	Benefits for EU economy and society
- **ANS productivity**: reduced en-route and TMA costs per flight	- Industrial leadership in ATM and aviation at the forefront of innovation
- **Operational efficiency for airspace users:** reduced fuel burn and flight time	- A more competitive EU aviation industry in the global aviation landscape
- **Capacity:** reduced delays, increased network throughput and throughput at congested airports	- Increased mobility with a lower environmental impact
- **Environment:** reduced CO_2 emissions	- Significant contribution to EU GDP and job creation
- **Safety and security:** high standards	- High standards in terms of safety, security and social standards

The figures in this Business View are represented as unit cost averages across the ECAC region. Absolute numbers are totals across the ECAC region — both for investment levels and for performance gains.

The Business View builds on the assumption that the necessary evolutions will materialise and that SESAR Solutions will be put into operation. This implies, for example, that new air-ground voice communication systems will be able to address the challenges arising from flight- or flow-centric operations, or that a regulatory framework may need to be developed to enable dynamic airspace configuration (DAC).

6.1.1 Impact on investment

Estimating investment levels up to 2035 is challenging as many of the SESAR Solutions are still in the early stages of R & D. To address this uncertainty, investment levels are expressed as ranges, while numerous industry experts from across the whole ATM and aviation value chains contributed to developing this edition of the Master Plan to ensure a high-level yet realistic business view.

Investment levels calculated for two distinct high-level options (see Chapter 5, Section 5.1) for rolling out SESAR have been considered to realise the Master Plan vision:

Option 1 — Optimised ATM infrastructure deployment: Total one-off investment ranging between EUR 18 billion and EUR 26 billion, of which EUR 15 billion to EUR 20 billion is required for the ground investment.

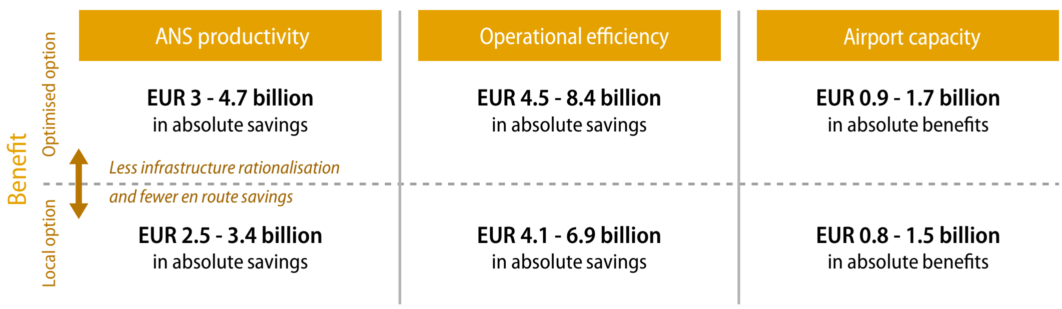
Option 2 — Local deployment: Total one-off investment levels ranging between EUR 19 billion and EUR 28 billion, including EUR 17 billion to EUR 26 billion for the ground investment (all values undiscounted).

The difference between the two options is particularly important for ground investments with savings of EUR 2 billion to EUR 6 billion:

- Air traffic control centres: Although it is assumed that all centres in the local deployment option are to be fully equipped with SESAR Solutions, the investment level is estimated to be 50 % lower for centres in the optimised ATM infrastructure deployment option (option 1). The explanation is that by deploying SESAR capabilities at fewer centres, only a light investment will be needed in other centres to unlock performance improvements at a network level.
- Military air traffic control centres: The investment level for military air traffic control centres is lower in the optimised ATM infrastructure deployment option (option 1), since greater integration/co-location between military and civil ANS for en-route service provision could be envisaged. The local deployment option (option 2) assumes the same level of integration as today, driving a higher investment level in military air traffic control centres seen from a European perspective.
- Airspace users: Investment is potentially higher in the optimised ATM infrastructure deployment option (option 1). This is due to a shorter deployment time in which airspace users must invest to retrofit a higher share of aircraft with SESAR Solutions in order to reach target equipage rates. However, these estimates may significantly evolve in the future as retrofit scenarios can be further optimised as SESAR Solutions become more mature.

This investment level covers deployment across the full ECAC region.

Figure 26 **Estimated performance ambition (undiscounted)**



NB: Undiscounted values. Numbers are rounded.

Source: ACE 2012 Benchmarking report, EUROCONTROL Challenges of Growth, WP 16.6, EUROCONTROL inputs for standard cost-benefit analysis.

6.1.2 Monetised benefits of the performance ambition

While Chapter 3 provides the overall performance ambition, this section quantifies direct monetary benefits; any secondary or indirect benefits are not considered. The benefits are expressed as the difference between the performance of the reference scenario (see Chapter 3) and the SESAR vision performance in 2035.

The performance ambition is quantified as monetary benefits for the following KPAs:

- ANS productivity/cost efficiency: reduced en-route and TMA direct costs per flight (recovered through ANS charges);
- operational efficiency for airspace users: reduced delay, fuel burn and flight time;
- airport capacity: additional throughput at congested airports.

Option 1 — Optimised ATM infrastructure deployment: Cost savings and the value of additional capacity will amount to annual recurring benefits of between EUR 8 billion and EUR 15 billion per year by 2035.

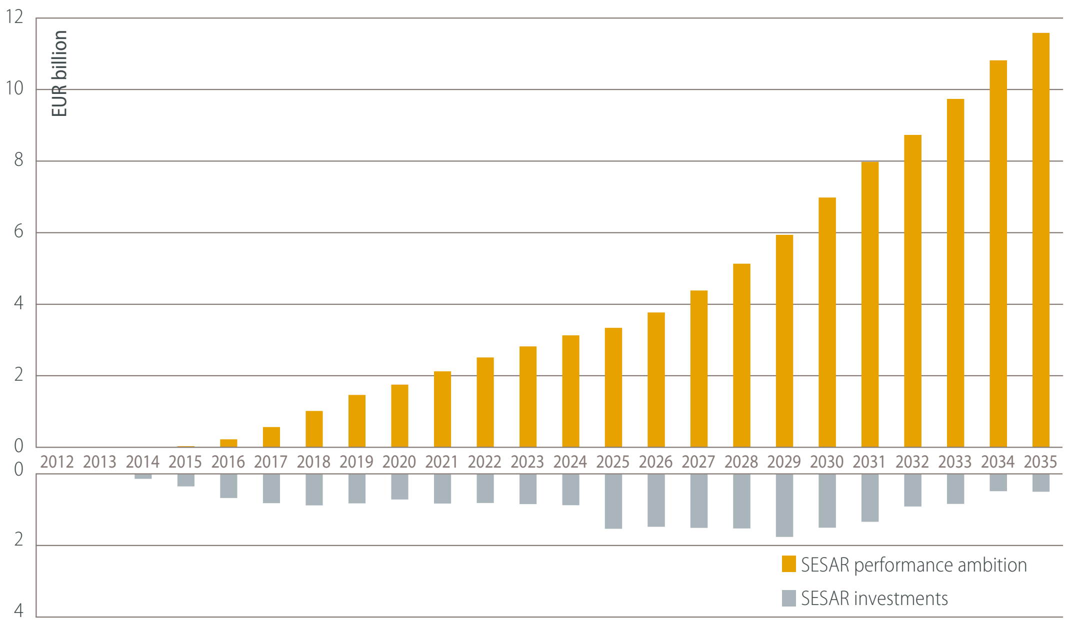
Option 2 — Local deployment: Cost savings and the value of additional capacity will amount to annual recurring benefits of between EUR 7 billion and EUR 12 billion per year for local deployment (44).

The 20 % difference in annual benefits from Option 1 is driven by a wider scope of infrastructure rationalisation and increased en-route operations savings.

The ratio between investment needs and the benefits obtained provides the overall positive Business View. The graph below, Figure 27, illustrates the outcome for the optimised ATM infrastructure deployment option where performance benefits outgrow the investment ambition as of 2018, and cumulative benefits outgrow cumulative investments as of 2020, assuming that all performance gains resulting from the performance scheme target-setting for

(44) Takes into account the difference in absolute performance ambition, not the difference in deployment speed.

Figure 27 **SESAR delivers significant value for Europe (undiscounted)**



Equals performance ambition minus investment ambition levels including RP2, PCP, SESAR 1 and SESAR 2020.
Does not take into account financing and restructuring costs.

NB: Scenario assuming optimal coordination to minimise investment and maximise benefits (optimised ATM infrastructure deployment option). As regards deployment, long tail mainly driven by air users and military.
The ATM community has gained confidence that part of the estimated performance ambition will be delivered, while the upper range of the estimated benefits is still to be confirmed through SESAR R & D and relies on high-level assumptions still to be consolidated (e.g. traffic level, synchronised industrialisation decisions, fuel price).

the period 2014-2019 (RP2) are realised. These figures do not take into account financing costs or potential restructuring costs, such as the cost of change, which are beyond SESAR and the scope of the Master Plan. It should be noted that the figure also incorporates the benefits achieved through the second performance reference period of the SES Performance Scheme (RP2).

The five-year difference in deployment time between the two options, together with the EUR 2 billion difference in overall investment levels and also the EUR 2 billion higher annual performance gain, result in a EUR 7 billion higher overall benefit in net present value (NPV) for the optimised ATM infrastructure deployment option as compared to the local deployment option.

While the overall business view would still be positive for local deployment, this EUR 7 billion lower NPV calls for a strong coordination role in deployment by the EU to:

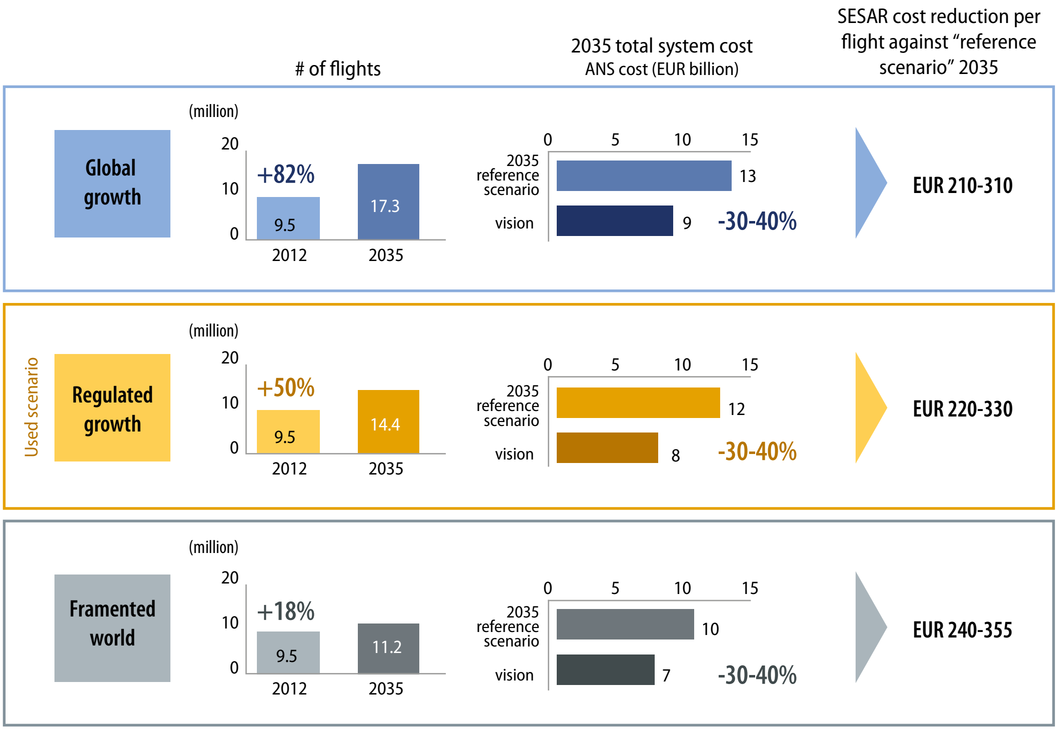
- optimise investments through clear coordination on how and where to invest;
- maximise performance gains by enabling integration and evolution of the ATM landscape;
- push the ambition timeline by actively promoting early standardisation and harmonisation of procedures;
- ensure benefits are realised fully and in good time by planning operational changes and deployment with a long-term horizon.

6.1.3 Traffic growth forecasts impact

The investment levels indicated in this section are based on assumed traffic growth of ~50 %, from 9.5 million flights in 2012 to 14.4 million flights in 2035, as indicated in the STATFOR 2035 Regulated Growth traffic forecast. The actual benefit in 2035 is sensitive to traffic growth, which is illustrated for ANS productivity (see Figure 28).

Even in a low growth scenario (+18 % in traffic by 2035), the SESAR vision would significantly reduce the ANSP unit cost from EUR ~960 per flight today to EUR ~600 per flight in 2035. Relative performance benefits for airspace users' operational efficiency are independent of traffic growth, while the need for airport capacity is reduced when traffic growth is lower than expected.

Figure 28 **Traffic growth impact on performance gains**



NB: Numbers are rounded. Source: ACE benchmarking report 2012, STATFOR.

6.2 Next SESAR deployment wave

Figure 29 **Path from validation targets to benefits**

This section provides the results of a high-level preliminary cost and benefit assessment (preliminary cost-benefit analysis) of the new Essential Operational Changes in the next wave of SESAR deployment, beyond PCP, as described in Chapter 4 (see Section 4.3) ([45]). Assumptions and further details can be found in the supporting document (available through the ATM Master Plan portal www.atmmasterplan.eu).

Only Essential Operational Changes (excluding those already included in the scope of the PCP) are included in the CBA.

The CBA includes the costs of the ATM Technology Changes required for the new Essential Operational Changes, as well as costs such as implementation and training costs.

The CBA monetises a range of benefits ([46]) which the new Essential Operational Changes are expected to bring, including increased ANS productivity, avoidance of ATFM delays and reduced fuel burn. Other benefits, not monetised, are also expected such as benefits in safety and security, avoidance of ATFM inconsistencies other than delay (e.g. flight cancellations, early arrivals), leading to greater flight predictability, additional movements at congested airports and more resilience in low visibility situations.

The new Essential Operational Changes also lay the ground for the implementation of SESAR 2020 in areas such as 4D trajectory management, CDM across the network and full SWIM services.

The benefits expected during the deployment phase are monetised in the CBA based on the validation results from the SESAR project available in mid-2014 (47) and may be adapted on the basis of future R & D results. The path from setting validation targets to the assessment of benefits in the CBA is shown in Figure 29.

The figures contained in this chapter are preliminary. They should be confirmed in the context of the definition of future common projects.

6.2.1 Preliminary CBA results

The CBA results cover the new Essential Operational Changes *(*excluding CNS rationalisation and LVPs using GBAS since more R & D is needed) for the following stakeholders ([48]):

- airport operators;
- airspace users: scheduled airlines (mainline and regional);
- ANSPs;
- Network Manager.

The CBA results show that between 2015 and 2035, the roll-out of new Essential Operational Changes would generate a NPV amounting to EUR 3.1 billion with an 8 % discount ([49]) rate. This results in an 11-year payback period (2026) based on the current deployment assumptions associated with new Essential Operational Changes. It should be noted, however, that the CBA is based on high-level deployment assumptions and scope for further optimisation of the deployment timing should be taken into account.

([45]) Two Essential Operational Changes are not included in the CBA: CNS rationalisation has been excluded due to the lack of data on all areas of infrastructure to be rationalised. This data is needed to estimate the costs and monetise the expected benefits. LVPs using GBAS have been excluded due to high uncertainty regarding the Airspace User costs.

([46]) Macro-economic benefits to the European economy are not considered in the CBA.

([47]) The CBA does not monetise the performance ambitions included in Chapter 2. However, the monetised benefit names have been aligned with the terms used in the performance ambition where applicable.

([48]) BA, GA IFR and Military airspace users are not included in the CBA because their benefits are currently underestimated due to difficulties in quantifying them. However, cost assessments have been performed for them and the results are included in Chapter 6.1.4. Costs for rotorcraft have not been assessed as the Essential Operational Changes do not currently target their specific needs.

([49]) Discounted values reflect that the value of money changes over time, so benefits received sooner have a higher value than those received further into the future, which become more uncertain. Undiscounted values reflect the real value of money, excluding the effect of time.

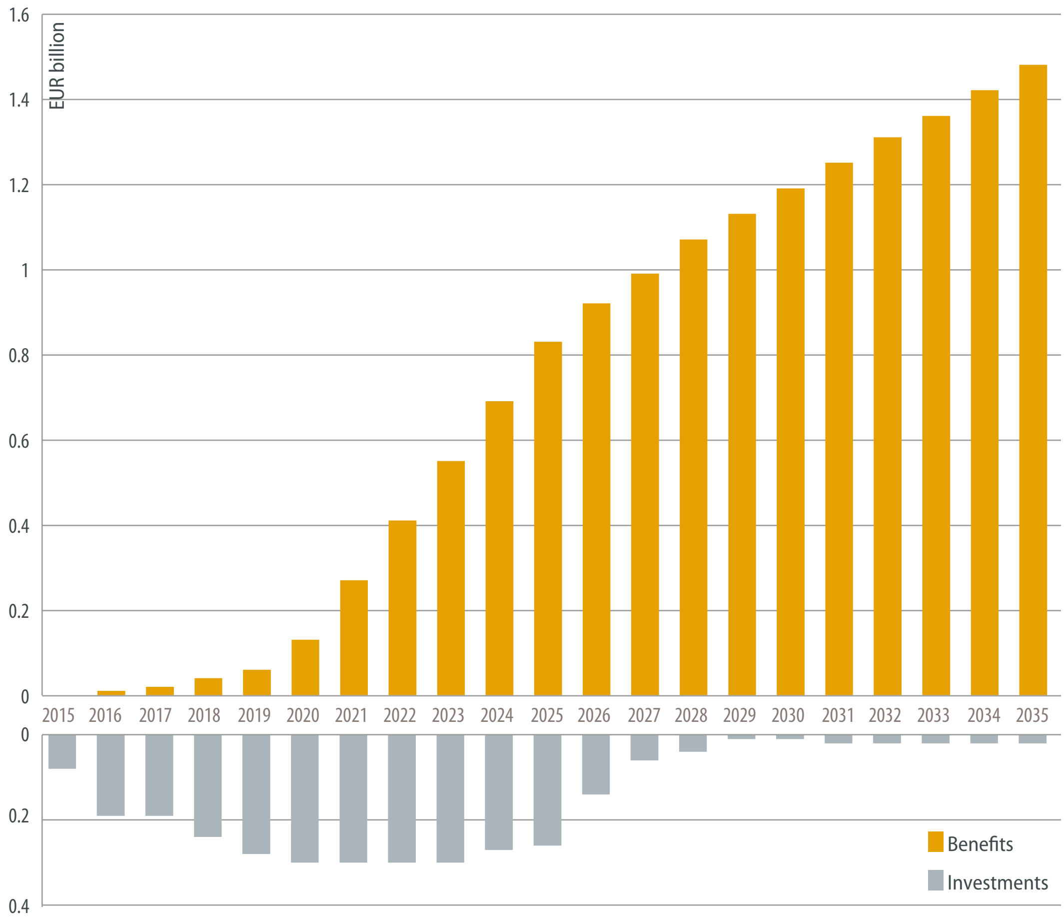
Figure 30 **Net benefits of New Essential Operational Changes**

Investment levels	Benefits	Net benefits
EUR 3.1 billion undiscounted (EUR 1.8 billion discounted)	EUR 15.1 billion undiscounted (EUR 4.9 billion discounted)	EUR 3.1 billion Net present value*

* Net present value is calculated as the difference between discounted figures of EUR 4.9 billion in benefits and EUR 1.8 billion in investments, assuming an annual discount rate of 8 %.

Figure 31 shows the distribution of costs and benefits over the CBA period.

Figure 31 **Investment levels and benefits of New Essential Operational Changes (undiscounted)**



6.2.2 Monetised benefits of the Essential Operational Changes

Figure 32 shows how overall monetised benefits are split across the different benefit types. The monetisation is dependent on the traffic growth and the timing of when benefits will be realised for each new Essential Operational Change.

The benefits associated with the PCP ATM functionalities are excluded from the CBA.

Figure 33 shows how the assessments in the different KPAs translate into stakeholder benefits in the CBA.

Details of the mechanisms through which the benefits are monetised are described in the supporting document.

Figure 32 **Breakdown of benefits (EUR billion) (undiscounted)**

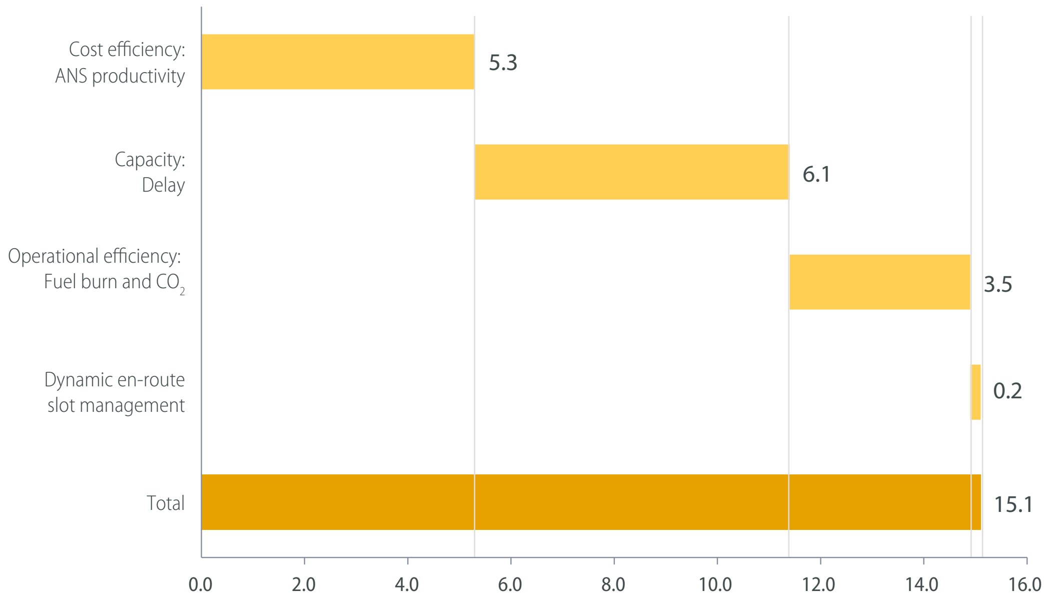


Figure 33 **Link between key performance areas and benefits**

Key performance area	Benefits
Cost efficiency: ANS productivity	Reduction in ANS operating costs for ANSPs Reduction in ANS charges per flight to airspace users
Capacity: Delay	Delay cost savings to airspace users
Operational efficiency: Fuel burn and CO_2	Fuel costs savings for airspace users CO_2 savings emission trading scheme — reduced costs for airspace users
Operational efficiency: Flexibility	Improved flexibility through user-driven prioritisation process (UDPP)

6.2.1 Costs of the Essential Operational Changes

This section presents the cost assessment of new Essential Operational Changes for the following stakeholders:

- airport operators;
- airspace users: scheduled airlines (mainline and regional);
- ANSPs;
- Network Manager.

Assumptions and further details can be found in the supporting document.

Cost assessment main assumptions

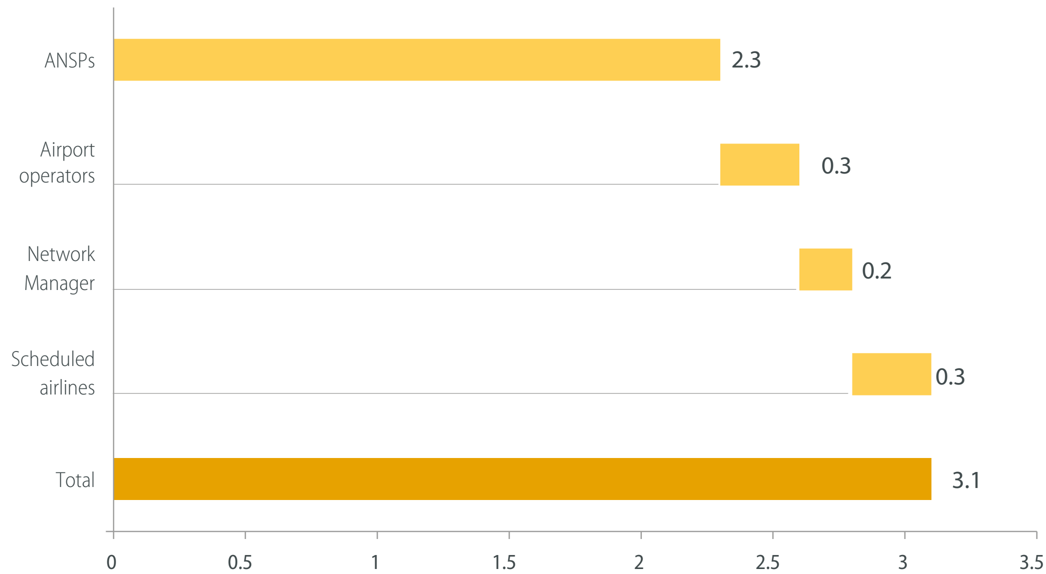
- Costs associated with the ATM Technology Changes that are needed for the PCP ATM functionalities are excluded.
- Costs associated with mandates such as datalink are not included.
- The deployment dates provided for new Essential Operational Changes will result in synchronised deployment between the stakeholders. There is one deployment period per new Essential Operational Change and per stakeholder group.
- ATM Technology Changes which enable multiple new Essential Operational Changes have only been costed once (so have not been double-counted).
- For airspace users, ANSPs and airport operators, the costs have been provided on a 'per unit' basis and were then multiplied by a number of investment instances. These investment instances generally focus on the high-complexity/high-utilisation locations.
- Costs provided represent the total cost of deploying new Essential Operational Changes. The costs include those related to procurement, implementation, integration, training, procedures and consultation. R & D costs are excluded as they are assumed to have already been incurred in the SESAR Development Phase.

Investment level assumptions per stakeholder in the CBA

ANSP investment levels were assessed via a bottom-up approach combining inputs from ANSPs and ground industry ([50]) to produce a range of 'per unit' costs for ATM Technology Changes (avoiding double counting) associated with each new Essential Operational Change. Costs were provided for en-route centres, TMAs and ANSP investments at airports. The investment instances costed for deployment are based on the 'Master Plan Level 2 ANSP' data, with a focus on the higher complexity locations. The overall investment costs were produced bottom-up and then revised from a top-down perspective to take account of savings that could be made through value engineering, collaboration between industry and ANSPs and economies of scale by delivering a coordinated programme of work throughout SESAR. The top-

([50]) The combined input of ANSPs, airports and ground industry in the cost assessments is a significant advance on previous costing exercises, where 'confidentiality issues' precluded such an approach.

Figure 34 **Investment levels by stakeholder included in the CBA (EUR billion) (undiscounted)**



down revision resulted in a reduction of costs by over one third.

Airport operator investment levels were assessed via a bottom-up approach, combining inputs from airport operators and ground industry to estimate a range of 'per unit' costs for each new Essential Operational Change at different categories of airport. The investment instances costed for deployment are based on the 'Master Plan Level 2 Airport' data, with a focus on the high-complexity/high-utilisation locations.

Network Manager (NM) investment levels were derived for the ATM Technology Changes in a bottom-up approach and indicate what the NM is required to deploy for new Essential Operational Changes. A network-centric approach was followed with the other stakeholders in line with the performance scheme. Where the costs could be attributed to either the NM or to other stakeholders, depending on the chosen method of implementation, an agreement was reached with relevant stakeholders to avoid double counting.

Scheduled airlines (mainline and regional) took a view on how to optimise their investments by assessing their fleet to consider the anticipated age of the aircraft and the regularity of their flights in European airspace, since these factors impact the number of aircraft to be retrofitted and hence the retrofit costs. The number of aircraft to be forward fitted was estimated based on the assumptions related to the evolution of the fleet and the target equipage rate needed for each ATM Technology Change to achieve the required performance. The reference costs are based on the Airbus Single Aisle family for scheduled airlines and on the ATR-72/ATR-42 family for regional airlines.

Scheduled airline investment levels were also assessed, taking into account investments at flight/airline operation centres and changes in operating costs. Costs related to ground (e.g. new certificates) and training (e.g. simulator or computer-based training) are estimated based on previous project experience, where available. It is estimated that scheduled airline investment levels will result in 42 % of the fleet being equipped for the ATM Technology Changes required for the Essential Operational Changes and not already included in the PCP or other mandates.

6.2.2 Investment levels and benefits for other stakeholders

This section addresses the impact on other stakeholders not included in the CBA due to limited data and inputs available at the time of publication of this plan. For instance, rotorcraft costs are not included as none of the Essential Operational Changes and associated operating environments are applicable.

Business aviation (BA) investment levels are estimated at EUR 0.31 billion, albeit only in respect of new Essential Operational Changes. Additional investments in different technologies will be needed to satisfy the specific needs of BA, including the specific or adapted technologies (e.g. CVS, EVS, and SVS). The European BA fleet is extremely varied and is customised for different operations in different ATM environments for the same aircraft. There is therefore a need for BA aircraft to be equipped with the latest SESAR technologies in order to maintain their current level of access to airports and airspace. Considering that the BA fleet is relatively young and the life expectancy of a business aircraft is in the range of 40-50 years, this will imply a significant number of aircraft to be retrofitted with various avionics. In addition, the business aviation fleet flies five to ten times less than scheduled airline fleets, which leads to complex depreciation of avionics over their lifespan and multiple avionics retrofitting programmes.

The difficulty for BA will be to quantify their specific benefits (e.g. door-to-door service improvement) and to ensure that those benefits will be sufficient to cover the investments. BA already anticipates that there will be reduced-cost avionics packages. For example, for forward fit applications on next generation aircraft, it is expected that most of new functionalities will be provided as part of the standard aircraft at no additional cost. In addition, global interoperability activities, avoiding multiple equipage packages and common solutions will need to be pursued.

General aviation (GA) includes both IFR and VFR flights, covering fixed wing and light VFR rotorcraft. Within both GA segments costs have been estimated excluding micro-light aircraft and lighter-than-air craft. The cost of equipage for IFR have been estimated at around EUR 0.28 billion. SESAR has not quantified the benefits derived from new Essential Operational Changes for GA since these do not address the needs of the GA community. Only investment levels are therefore shown in this edition of the Master Plan, although some ATM Technology Changes provide safety benefits.

In setting investment levels, GA compliance is assumed with essential ATM Technology Changes (e.g. ADS-B out), even though no existing regulatory instruments make such demands for the majority of GA aircraft. This equipage is assumed to be required to deliver the overall network benefits of specific new Essential Operational Changes requiring the majority of GA to equip with certain ATM Technology Changes. Further clarification will be needed on what equipage rates are required to realise most operational benefits.

GA technical solutions do not yet exist, nor are they in development within Europe, to address ATM Technology Changes. Since the ATM Technology Changes in the new Essential Operational Changes are not relevant to GA (e.g. LVPs using GBAS CAT II/III) the cost per aircraft for each new Essential Operational Change is less than for other airspace users. The costs include only ATM Technology Changes deemed necessary to deliver the network benefits. It is expected that the certification standards will also be proportionate, thus assisting the cost reduction. Innovative and tailored solutions will be required for smaller GA aircraft to support the objectives of the ATM Technology Changes (e.g. datalink, i4D etc.). The typical IFR aircraft cost is therefore between EUR 10 000 and EUR 16 000 at current market prices, in addition to costs borne through PCP compliance.

The Military is an airspace user, ANSP and airport operator. Military costs (air and ground) are based on the relevant civil 'per unit' cost values. The military airspace user costs consider the civil 'per unit' costs and the military fleet (large aircraft, light trainers, fighters) and were assessed at around EUR 0.09 billion[51]. The military also has a large helicopter fleet, but since costs are not available for civil rotorcraft, they are also unavailable for the purpose of military calculations.

The overall military ground investment level (ANSP and airport) is not calculated as the number of military units is not currently available. However, it is clear that system integration with civil ANSPs at national or regional level will decrease costs for the military. Examples of integrated civil-military systems have shown that the cost for the military is between 5 % and 20 % of the total cost for civil ANSPs.

In addition, the cost of upgrading multinational air command and control systems and national air defence systems to SESAR requirements is assumed to be similar to the cost of upgrading a civil ATM system.

(51) This edition of the European ATM Master Plan incorporates a preliminary assessment of military investment costs. At this stage, the full range of military data is not yet completely available for the full scope of the Master Plan: this assessment should therefore be considered as an initial input.

Military benefits are not monetised within the CBA, but benefits can be expected if the following high-level military operational and system needs are met:

- unrestricted access to airspace aimed at safeguarding the integrity of national airspace and the provision of support to civil authorities in connection with national security;
- unconstrained training to ensure the readiness of military forces (including police and customs) to perform the activities required and to test systems or operational concepts;
- accessibility to civil/military airports;
- flight and cost efficient transit to operating and training areas;
- ensuring that national airspace is accessible for national and international forces including cross-border operations and access to cross-border ATM resources;
- processes and mechanisms supporting performance-based certification so that an equivalent level of performance of the military system against SESAR ATM/CNS requirements can be achieved.

Military stakeholders can expect to see benefits related to capacity, cost effectiveness, efficiency, flexibility, access and equity, interoperability and (national) security.

6.3 Incentivisation strategy and possible areas of regulation

6.3.1 Synchronisation of operational changes

According to European Commission Implementing Regulation (EU) No 409/2013 on the definition of common projects, the Master Plan provides the basis for timely, coordinated and synchronised deployment of Operational Changes. A timely, coordinated and synchronised deployment of SESAR is essential to achieving the SES performance objectives and the overall economic benefits expected from ATM modernisation.

Still, not all Operational Changes need to be synchronised. According to the above regulation, the need for synchronised deployment of ATM functionalities needs to be assessed on the basis of:

a) defined geographical scope and planning for the changes, including deployment target dates;
b) identification of the operational stakeholders required to deploy them;
c) transitional measures for their progressive deployment.

Criterion (b) above is particularly important, given that the involvement of a large number of different stakeholders implies the need for strong deployment coordination to allow the exchange of information across ground-ground and air-ground interfaces, and to ensure interoperability.

A full impact assessment should be undertaken to confirm the need for the synchronisation of Operational Changes and for their deployment, and to verify that they deliver the right solution for the identified problem, as well as a solid business case.

6.3.2 Incentivisation strategies

The need for incentives

A timely, coordinated and synchronised deployment of SESAR is essential to achieve the SESAR performance ambition levels outlined in the Master Plan. According to European Commission Implementing Regulation (EU) No 409/2013 on the definition of common projects, the Master Plan provides the basis for timely, coordinated and synchronised deployment of the Operational Changes. This regulation also foresees the use of incentives 'in particular to mitigate negative impacts on a specific geographical area or category of operational stakeholders'.

A long-standing issue associated with the deployment of new ATM Technology Changes is the matter of 'last mover advantage'. In the case of airspace users, this situation exists due to limited benefits often derived by those who invest first in new technologies since ANSPs operate on a 'first come, first served' basis and consider that a 'critical mass' of operations is needed in order to incorporate new procedures or approaches into service. This long-standing approach must change if SESAR is to be deployed in a timely and synchronised manner.

The main driver for providing an incentive for a certain SESAR capability is therefore to de-risk the transition towards its desired full implementation. This should be done by addressing, in due course, the following implementation challenges:

- ensuring synchronisation (including alignment of requirements) and timely deployment;
- mitigating negative business cases either for some specific capabilities or specific stakeholder categories;
- encouraging and securing on-time equipage of aircraft and overcoming the issue of last mover advantage;
- compensating possible negative cash flow during the transition phase (long payback times) and avoiding pre-financing by airspace users.

Range of options

To overcome the aforementioned challenges, a range of incentive tools should be considered, possibly in combination, namely:

Financial

- European Union funding through the Connecting Europe Facility (CEF) framework, focusing on implementation projects for SESAR deployment. This funding may be allocated to operational stakeholders on a non-discriminatory basis. Frontloading of grants would accelerate the decision of airspace users to equip their fleet early.
- Incentives are possible in relation to the performance and charging regulations in the form of ANS charge modulation, which could accelerate the deployment of SESAR Solutions and provide incentives to equip aircraft. However, this tool presents a number of challenges and would need further detailed work to assess how it could actually be feasible in practice.
- Loan guarantees or loans from the European Investment Bank (as indicated in the CEF Regulation) could provide airspace users, ANSPs and airports with a good bridging solution in order to cope with their return-on-investment time constraints.

Operational

- The principle of 'first come, first served' must evolve to take into account an approach that recognises and leverages aircraft capability to secure more efficient and effective performance. This principle has been applied to manage air traffic flows, which does not necessarily promote the most efficient use of ATM capabilities, meaning both systems and procedures. Furthermore, this principle does not necessarily guarantee the most efficient and effective handling of mixed capabilities. To optimise European ATM, the principle of 'most capable, best served' (MCBS) could be considered to ensure that the most capable flights receive a preferential service and get operational benefits as early as possible. MCBS is a promising concept which needs to be defined on a case-by-case basis and integrated into the currently applied principle of 'first come, first served'.

7 Risk Management

7 Risk Management

7.1 Capturing and analysing risk

In looking at risk management, the Master Plan addresses the most significant risks associated with the delivery of the Essential Operational Changes for achieving the outlined performance ambitions (see Chapter 3). Determining risks does not imply that they will actually materialise, rather that these risks have been identified and are adequately managed so that they do not impact the delivery of the Master Plan.

A Master Plan risk may be defined as an undesired event or series of events, which reduce confidence in the Master Plan. Their occurrence may represent a potential obstacle towards delivering the timely, coordinated and efficient deployment of the new technologies and procedures in line with the SESAR Target Concept.

As part of the 2015 Master Plan campaign, a review and update of the risks highlighted in the previous edition was undertaken using the SJU risk management framework. Risks were identified according to their relation to the achievement of the performance ambitions reflected in the Master Plan. Risks which have a significant impact on implementation of the SESAR project or its subsequent deployment were also analysed. While the risk analysis covered all potential areas in a comprehensive way, this section focuses on the risks with the highest criticality.

All identified risks have been addressed through mitigation action plans recorded within the SJU risk management framework. Each mitigation action identifies dedicated ownership and a target date in order on one hand to reduce the likelihood of the event materialising and on the other hand to reduce the possible impact, thus increasing confidence in the Master Plan. Section 7.2 details the actors and actions to mitigate the highly critical risks identified. More detailed action plans are captured in the SJU risk management framework.

By necessity, risk management is an ongoing process in which regular monitoring is required of the status of the ongoing mitigation actions. In between Master Plan updates, a regular review of all risks and mitigation actions is conducted by the SJU.

7.2 Identified high-priority risks

Risk	Description	Consequences/Impact	Mitigation/Actions
1. The R & D Programme does not deliver solutions that are ready for preparation for deployment.	Lack of efficiency leading to the delivery of SESAR Solutions which are not fully ready for preparation for deployment.	▪ Delay to deployment plans related to SESAR R & D results. ▪ Performance ambition is not met.	By: SJU Action: ▪ Ensure consistency between the expectations outlined in the Master Plan and the delivery of SESAR Solutions in terms of time and scope. ▪ Deliver and publish SESAR Solution Packs to prepare for deployment of the first SESAR R & D results.
2. The transition from SESAR 1 to SESAR 2020 causes delays and discontinuation of R & D activities.	The Master Plan should ensure the integrity and consistency of the entire SESAR project from development to deployment. Continuity should be maintained between the two activities.	▪ An interruption in the planning and monitoring of this process, at any stage, will substantially compromise the successful and coherent modernisation of European ATM. ▪ Capacity of ATM to meet the performance ambitions is undermined, with a negative impact on the industrialisation processes and consequently on synchronisation of deployment.	By: EC, SJU Action: ▪ Ensure a good transition plan from SESAR 1 to SESAR 2020 in order to guarantee the seamless continuation of all activities required for the modernisation of European ATM. ▪ Ensure the adequate documentation of all relevant R & D output and the identification and storage of all results, necessary to ensure continuity of ATM R & D and deployment planning activities supporting the execution of the Master Plan.
3. Ineffective bridging between development and deployment activities may put industrialisation at risk and delay deployment.	Ineffective bridging between R & D and industrialisation/deployment leads to inefficiencies, in particular for third parties (non-SJU members) and the SESAR Deployment Manager (SDM). Regulatory and standardisation needs to support harmonised deployment are not met.	▪ Delays and lack of harmonisation in deployment. ▪ Performance ambition is not met. ▪ Compromise to the delivery of enhanced performance due to reliance on 'workarounds' to secure regulatory approval. ▪ The full scope of industrialisation may be missed, omitting certain stakeholders' needs.	By: EC, SJU, SDM, standardisation bodies Action: ▪ Launch first wave of SESAR Very Large Scale Demonstration activities to bridge R & D with deployment in the context of SESAR 2020. ▪ Strengthen cooperation arrangements with standardisation bodies to ensure alignment of their respective work programmes with the needs identified in the Master Plan. ▪ Strengthen current engagement of the regulatory authorities in the development phase to prepare for deployment.
4. Interoperability and global harmonisation are not ensured.	Interoperability and global harmonisation rely on the synchronised application of standards and common principles, together with common technical and operational solutions for relevant aircraft and ATM systems. This includes civil-military interoperability.	▪ Global modernisation programmes are not aligned. ▪ Reworking required, resulting in delays in development and increased development costs. ▪ Basis for sound investment decision-making is not established. ▪ Delay of the deployment of the Programme.	By: EC, SJU Action: ▪ Work towards global interoperability in the framework of ICAO working arrangements. ▪ Continue to strengthen SESAR/NextGen coordination under the EU/US MoC with particular focus on securing further alignment between the Master Plan and the NextGen Implementation Plan.

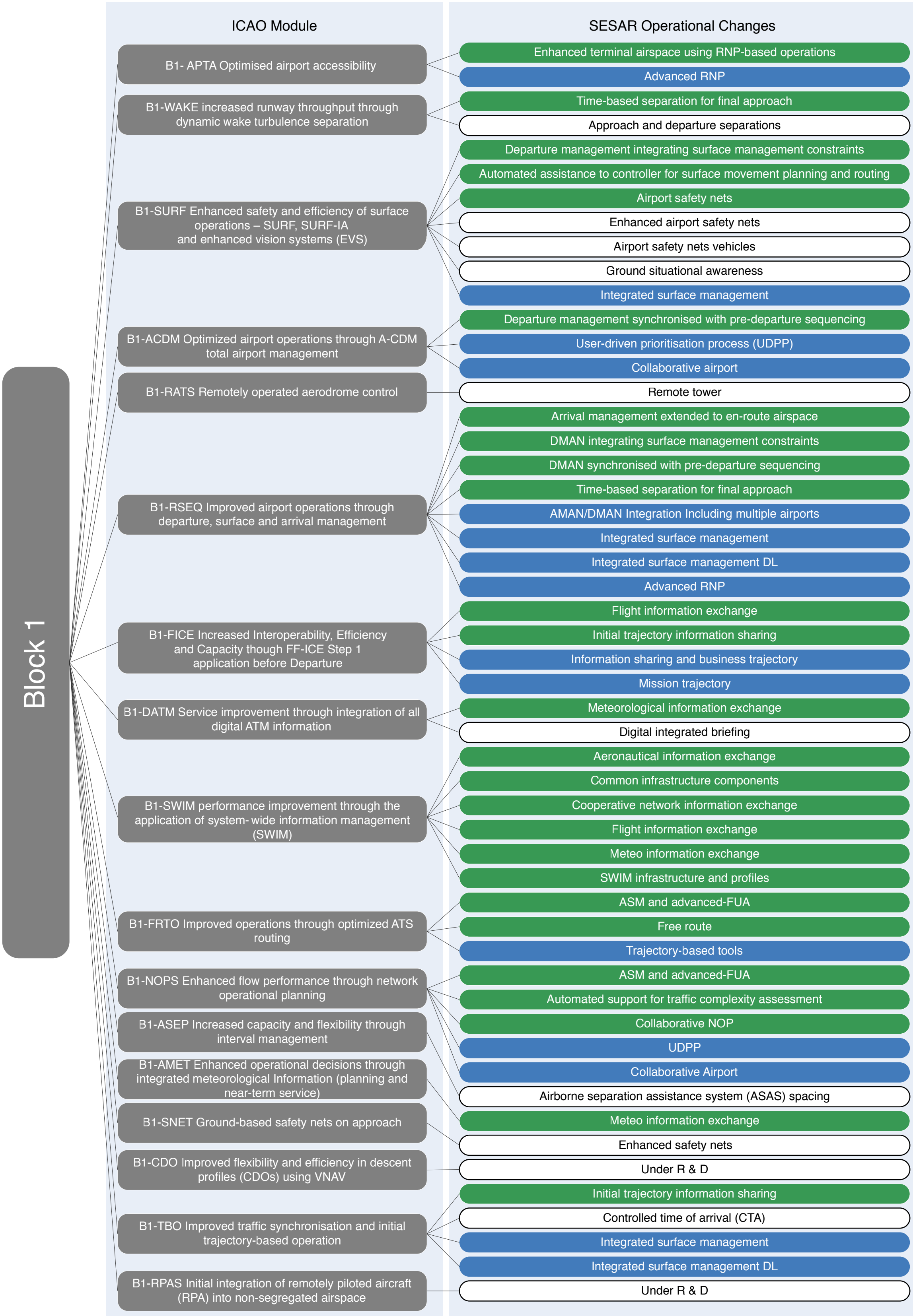
Risk	Description	Consequences/Impact	Mitigation/Actions
5. Delays in the implementation of the Pilot Common Project (PCP).	The Pilot Common Project (PCP) provides the first wave of deployment of SESAR R & D results.	▪ Insufficient commitment for the deployment phase. ▪ Delay/de-synchronisation of deployment plans related to the first SESAR R & D results. ▪ Performance ambition is not met. ▪ Negative impact on the EU economy, employment, mobility and the environment.	By: EC, SDM, and all stakeholders Action: ▪ Synchronisation and coordination by SDM. ▪ Ensure a strong promotion of the Deployment Programme. ▪ Identify, stabilise and ensure implementation of elements that are prerequisites for SESAR deployment and/or essential for contributing to the performance ambition. ▪ Implement the pre-SESAR changes and the PCP precursors according to stakeholder roadmaps.
6. Investments to support deployment beyond 2020 are not secured.	The roll-out of the SESAR vision relies on coordinated timing of investments to ensure synchronised deployment (coordinated deployment and incentivisation).	▪ Performance ambition is not met. ▪ Insufficient commitment, financial resources and investment for the deployment phase. ▪ Delay/de-synchronisation of deployment. ▪ Severe negative impact on the EU economy, employment, mobility and environment.	By: EC, SJU, SDM Action: ▪ Prepare for the deployment of SESAR R & D results (business cases, impact assessments, future common projects when appropriate). ▪ Ensure that financial and operational incentive mechanisms are defined and implemented in a timely manner in order to facilitate the deployment of SESAR. ▪ Ensure consistency between the stakeholder roadmaps in the Master Plan and stakeholders' investment plans.
7. Governance structure is not capable of ensuring successful deployment.	The governance structure is not capable of ensuring a strong link between SESAR development and deployment activities.	▪ Lack of accountability between the various actors. ▪ Delay/de-synchronisation of deployment. ▪ Performance ambition is not met. ▪ Severe negative impact on the EU economy, employment, mobility and the environment.	By: EC (assisted by PRB), SDM, SJU, EUROCONTROL and all stakeholders Action: ▪ Define and implement an appropriate deployment governance mechanism and efficient interaction of all parties involved in order to ensure an effective execution of the Deployment Programme consistently with the Master Plan and the Network Strategy Plan. ▪ Governance has to ensure that the required resources are available for timely local and synchronised deployment. ▪ Further improve SESAR development and deployment reporting mechanisms concerning the execution of the Master Plan now that the 3 phases of the SESAR life cycle are active: definition, development and deployment.

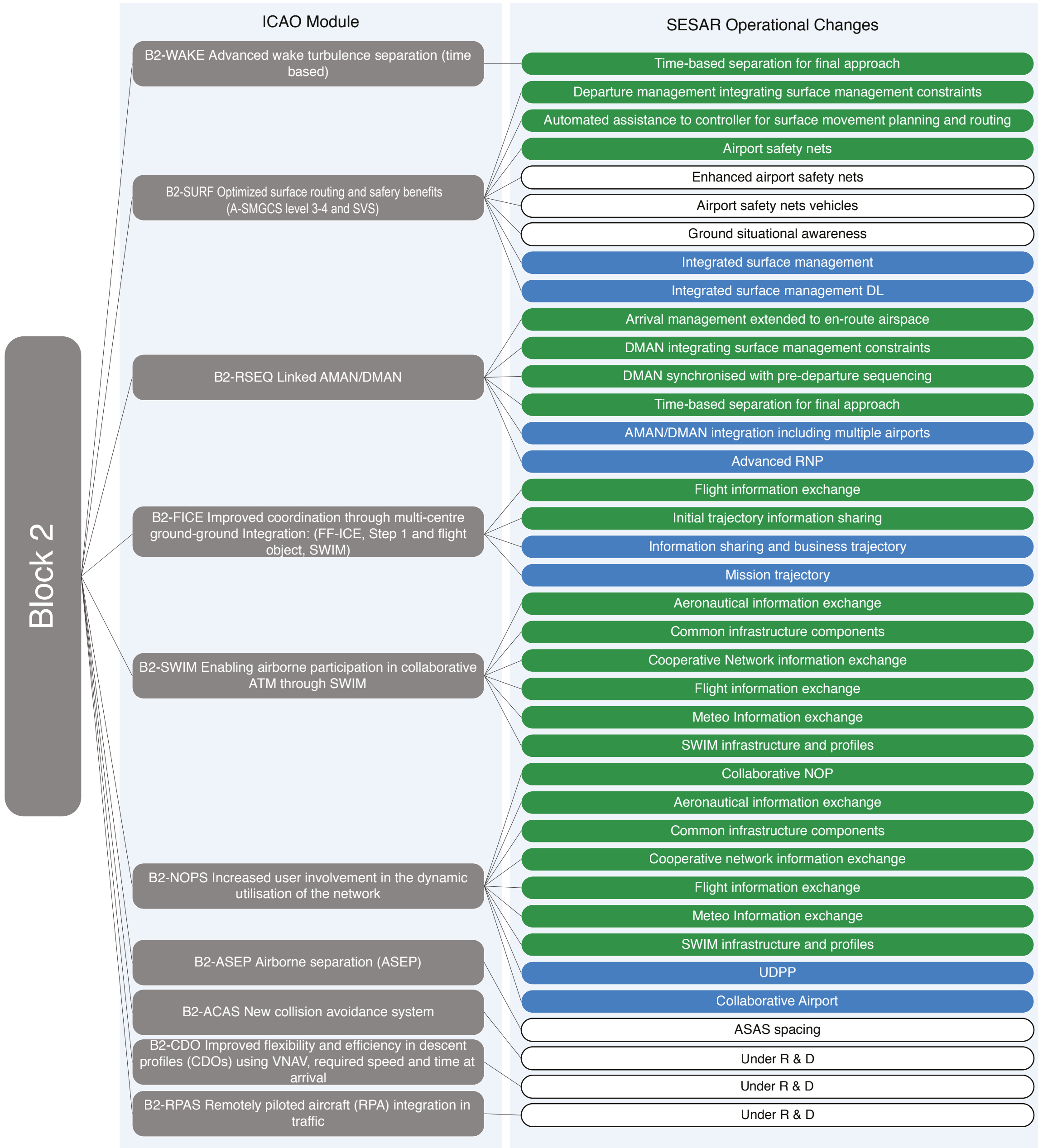
Risk	Description	Consequences/Impact	Mitigation/Actions
8. Deployment of SESAR Solutions leads to unaddressed cybersecurity vulnerabilities.	The R & D programme must set clear guidance to ensure that delivered solutions can be made secure, are securely integrated into operational ATM systems (including legacy systems) and contribute to a resilient European ATM system.	▪ While serious incidents are likely to be very infrequent, they may have very serious consequences; even a trickle of low impact incidents will erode trust in the system and could delay SESAR deployment and benefits.	By: EC. SJU Action: ▪ Ensure efforts on ATM cybersecurity are coordinated, and assess policy options for strengthening cybersecurity and resilience. ▪ Establish principles and processes for ensuring cybersecurity and resilience are included appropriately within the SESAR R & D work programme.
9. Failure to manage human performance (human factors, competency and change management) issues in the development and implementation of the Target Concept.	▪ Human factors are not integrated into concepts, development and validation (with operational staff), including applying minimal standards and unrealistic assumptions (especially human workload and automation). ▪ Lack of appropriate competency (training and assessment) regulatory, certification, training and assessment framework. ▪ Lack of verified and competent human resources to support operations in a new technological environment (timely and in sufficient numbers). ▪ Absence of appropriate social and change management processes and social dialogue structures at European, national and local levels. ▪ Lack of an integrated and consistent approach (consistency between regulatory and working bodies).	▪ Without addressing these risks the future European ATM System will not fully achieve its objectives. ▪ Risk of additional safety hazards.	By: SJU and all stakeholders Action: ▪ Ensure that operational staff are included in development and R & D validation activities. ▪ Issue regular recommendations and activity plans for Human Performance in the area of R & D, regulation, standards, and management at industry level. ▪ Monitor all SESAR-oriented R & D and validation phases regarding Human Performance standards, methods and requirements. ▪ Examine staffing implications of all deployment activities for all groups of operational aviation staff and publish results and related recommendations. ▪ Ensure appropriate coordination between all stakeholders concerned to ensure consistency between initiatives related to human factors, competency and social dialogue.

Annexes

Annex A: Mapping SESAR Operational Changes — ICAO Aviation System Block Upgrades

The mapping between SESAR Operational Changes and ICAO's ASBU initiative is highlighted in this annex. The PCP Essential Operational Changes are highlighted are highlighted in green. New Essential Operational Changes are highlighted in blue, while other operational changes are shown in white.




Block 2
ICAO Module
SESAR Operational Changes
B2-WAKE Advanced wake turbulence separation (time based)
B2-SURF Optimized surface routing and safery benefits (A-SMGCS level 3-4 and SVS)
B2-RSEQ Linked AMAN/DMAN
B2-FICE Improved coordination through multi-centre ground-ground Integration: (FF-ICE, Step 1 and flight object, SWIM)
B2-SWIM Enabling airborne participation in collaborative ATM through SWIM
B2-NOPS Increased user involvement in the dynamic utilisation of the network
B2-ASEP Airborne separation (ASEP)
B2-ACAS New collision avoidance system
B2-CDO Improved flexibility and efficiency in descent profiles (CDOs) using VNAV, required speed and time at arrival
B2-RPAS Remotely piloted aircraft (RPA) integration in traffic
Time-based separation for final approach
Departure management integrating surface management constraints
Automated assistance to controller for surface movement planning and routing
Airport safety nets
Enhanced airport safety nets
Airport safety nets vehicles
Ground situational awareness
Integrated surface management
Integrated surface management DL
Arrival management extended to en-route airspace
DMAN integrating surface management constraints
DMAN synchronised with pre-departure sequencing
Time-based separation for final approach
AMAN/DMAN integration including multiple airports
Advanced RNP
Flight information exchange
Initial trajectory information sharing
Information sharing and business trajectory
Mission trajectory
Aeronautical information exchange
Common infrastructure components
Cooperative Network information exchange
Flight information exchange
Meteo Information exchange
SWIM infrastructure and profiles
Collaborative NOP
Aeronautical information exchange
Common infrastructure components
Cooperative network information exchange
Flight information exchange
Meteo Information exchange
SWIM infrastructure and profiles
UDPP
Collaborative Airport
ASAS spacing
Under R & D
Under R & D
Under R & D

Annex B: Avionics roadmap([52])

Operational Change	ATM Technology Change	Key feature	Airspace user	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Initial trajectory information sharing (PCP AF6)	ATN baseline 2 datalink systems and services - Trajectory downlink capacity-ADS-C EPP	Enabling aviation infrastructure	Mainline				▲						
			Regional						▲				
			BA				▲						
			Rotorcraft						▲				
			Military								▲		
Enhanced visual operations (For opreations down to 100 feet)	. Enhanced vision system . Synthetic vision system	High-performing airport operations	Mainline						▲				
			Regional				▲						
			BA	◄									
			Rotorcraft	◄									
			Military	Not applicable									
Advanced RNP	FMS upgrade for advanced RNP - RNP0.3 approach (Baro or SBAS)	Advanced air traffic services	Mainline	◄									
			Regional	▲									
			BA	◄									
			Rotorcraft	Not applicable									
			Military										▲
. Enhanced airport safety nets . Approach & departure separations . Ground situational awareness . ASAS spacing . Trajectory based tools	ADS-B OUT capacity (compliant with DO-260B) as per SPI IR	Enabling aviation infrastructure	Mainline	▲									
			Regional	▲									
			BA	◄									
			Rotorcraft	◄									
			Military	▲									
Integrated surface management	Manual D-TAXI	High-performing airport operations	Mainline					▲					
			Regional							▲			
			BA				▲						
			Rotorcraft						▲				
			Military					▲					
LVP using GBAS	Initial GBAS Cat II/III using GPS L1	High-performing airport operations	Mainline			▲							
			Regional	No plan									
			BA			▲							
			Rotorcraft	Not applicable									
			Military	Not applicable									
Mission trajectory	FMS capability to support mission trajectory	Advanced air traffic services	Military										▲
i4D (CTA)	ATN baseline 2 datalink systems and services - Advanced datalink capabilities - CPDLC	Advanced air traffic services	Mainline				▲						
			Regional						▲				
			BA				▲						
			Rotorcraft										
			Military								▲		
CTA	FMS capability to support i4D operations	Advanced air traffic services	Mainline				▲						
			Regional						▲				
			BA				▲						
			Rotorcraft						▲				
Enhanced airport safety nets	Situational awareness and onboard alerts on ground at proximity of runway (SURF-IA)	High-performing airport operations	Mainline					▲					
			Regional						▲				
			BA						▲				
			Rotorcraft								▲		
			Military								▲		
ASAS spacing	ASPA (ASAS spacing) and CAVS (CDTI assisted visual separation)	Advanced air traffic services	Mainline						▲				
			Regional						▲				
			BA				▲						
			Rotorcraft								▲		
			Military										▲
Enhanced visual operations (For operations down to touch down)	Combined vision capabilities* . + take-off . + taxi	High-performing airport operations	Mainline	No plan									
			Regional	No plan									
			BA					▲					
			Rotorcraft						▲				
			Military	Not applicable									

* The availability date for the first capability is shown on the road map

Legend
- PCP ATM technology changes
- Pre-SESAR
- ATM technology changes supporting essentials changes
- Mature for deployment at local level
- ATM Technology changes supporting R&D activities
- ▲ IOC dates for ATM technology changes
- ◄ IOC dates for ATM technology changes which started before 2015

- Advanced air traffic services
- High-performing airport operations
- Enabling aviation infrastructure

([52]) At the moment of adopting this document, the avionics roadmap does not cover all airspace user categories, and in particular General Aviation. This aspect will be covered in the activities of maintenance of the Master Plan.

Annex C: List of abbreviations

4D	4 dimensional
A/G	Air/ground
ACAS	Airborne collision avoidance system
ACC	Area control centre
A-CDM	Airport-CDM
ADD	Aircraft-derived data
ADS	Automatic dependent surveillance
ADS-B	ADS–Broadcast
ADS-C	ADS-Contract
AeroMACS	Aeronautical mobile airport communications system
AFISO	Aerodrome flight information service officer
A-FUA	Advanced flexible use of airspace
AGL	Airfield ground lighting
AIM	Aeronautical information Management
AIRM	Aeronautical information reference model
AIS	Aeronautical information service
AMAN	Arrival manager
AMHS	Aeronautical/ATS message handling system
ANB	Air navigation bureau
ANS	Air navigation services
ANSP	Air navigation service provider
AO	Airport operations
AOM	Airspace organisation management
AOP	Airport operations plan
APAMS	Airport performance assessment monitoring system
A-PNT	Alternative position, navigation and timing
APOC	Airport operations centre
ARES	Airspace reservation
A-RNP	Advanced-RNP
ASAS	Airborne separation assistance system
ASBU	Aviation System Blocks Upgrades
ASD	AeroSpace and Defence Industries Association of Europe
ASM	Airspace management
A-SMGCS	Advanced surface movement guidance and control system
ASPA	ASAS spacing
ATC	Air traffic control
ATCO	Air traffic controller
ATFCM	Air traffic flow and capacity management
ATFM	Air traffic flow management
ATFN	Aeronautical fixed telecommunication network
ATM	Air traffic management
ATMRPP	ICAO ATM requirements and performance panel
ATN	Aeronautical telecommunications network
ATSA-AIRB	Air traffic situational awareness-airborne
ATSAW	Air traffic situational awareness
ATSEP	Air traffic safety electronics personnel
ATV	Airport transit view
AUO	Airspace user operations
AUP	Airspace use plan
B2B	Business-to-business
BA	Business aviation
CAPP	CDTI assisted pilot procedure
CAVS	CDTI assisted visual separation
CBA	Cost benefit analysis
CCS	Capacity-constrained situations
CDM	Collaborative decision-making
CDTI	Cockpit display of traffic information
CEF	Connecting Europe Facility

CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CIDIN	Common ICAO Data Interchange Network
CIIP	Critical information infrastructure protection
CM	Conflict management
CNS	Communications, navigation and surveillance
COTS	Commercial-off-the-shelf
CTA	Controlled time of arrival
CTOT	Calculated take-off time
CVS	Combined vision system
CWP	Controller working position
D & A	Detect and avoid
DAC	Dynamic airspace configuration
DCB	Demand and capacity balancing
DL	Datalink
DMAN	Departure manager
DME	Distance measuring equipment
D-NOTAM	Digital-notice to airmen
DRA	Direct routing airspace
DSB	Digital side band
D-TAXI	Datalink taxi support
E-AMAN	Extended arrival management
EASA	European Aviation Safety Agency
EASCG	European ATM Standards Coordination Group
eATM	European ATM
EATMN	European ATM Network
EC	European Commission
ECA	European Cockpit Association
ECAC	European Civil Aviation Conference
EDA	European Defence Agency
EFPL	Extended flight plan
EGNOS	European Geostationary Navigation Overlay Service
EPP	Extended projected profile
EREA	Association of European Research Establishments for Aeronautics
ESA	European Space Agency
ESSIP	European Single Sky ImPlementation
ETSI	European Telecommunications Standards Institute
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment
EVS	Enhanced vision system
FAA	Federal aviation administration
FAB	Functional airspace block
FCI	Future communications infrastructure
FDP	Flight data processing
FDPS	Flight data processing system
FF-ICE	Flight and flow information in a collaborative environment
FIR	Flight information region
FIS-B	Flight information system — broadcast
FMP	Flow management position
FMTP	Flight message transfer protocol
FOC	Flight operations centre
FRA	Free routing airspace
FSS	Fixed satellite system
FUA	Flexible use of airspace
G-G	Ground-ground
GA	General aviation
GANP	Global Air Navigation Plan
GASP	Global Aviation Safety Plan
GAST	GBAS Approach Service Type
GAT	General air traffic
GBAS	Ground-based augmentation system
GDP	Gross domestic product
GFT	Global flight tracking
GNSS	Global navigation satellite system
GPS	Global positioning system
HMI	Human machine interface
HUCL	High utilisation complex Layout
HUSL	High utilisation simple layout

i4D	initial 4D
ICAO	International Civil Aviation Organisation
ICNS	Integrated CNS
IFR	Instrument flight rules
ILS	Instrument landing system
IM	Interval management
IMP	Information management protocol
IOC	Initial operating capability
IP	Internet protocol
IPS	Internet protocol suite
IR	Implementing rule
iRBT	Initial reference business trajectory
iRMT	Initial reference mission trajectory
IRS	Inertial reference system
iSBT	Initial shared business trajectory
iSMT	Initial shared mission trajectory
ISRM	Information service reference model
IT	Information technology
ITF	In trail follow
ITM	In trail merge
ITU	International Telecommunication Union
IVT	International validation team
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
KPA	Key performance area
KPI	Key performance indicator
L-DACS	L-Band digital aeronautical communication system
LNAV	Lateral navigation
LUCL	Low utilisation complex layout
LUSL	Low utilisation simple layout
LVC	Low visibility conditions
LVP	Low visibility procedure
MC/MF	Multi-constellation/multi-frequency
MET	Meteorology/Meteorological information
MLAT	Multilateration
MLS	Microwave landing system
MoC	Memorandum of cooperation
MOE	Military operating environment
MON	Minimum operational network
MONA	Monitoring aids
MSP	Multi-sector planner
MSPSR	Multi-static primary surveillance radar
MSSR	Mono-pulse secondary surveillance radar
MT	Mission trajectory
N/A	Not applicable
NATO	North Atlantic Treaty Organization
NDB	Non-directional beacon
NM	Network Manager
NOP	Network operations plan
NPV	Net present value
OBT	Off-block time
P3R3	Prevision, prevention, protection, recognition, response, and recovery
PBN	Performance-based navigation
PCP	Pilot Common Project
PENS	Pan-European network service
PinS	Point in space
PKI	Public key infrastructure
PRB	Performance Review Body
PRNAV	Precision area navigation
PSR	Primary surveillance radar
R & D	Research and development
RA	Resolution advisory
RBT	Reference business trajectory
RC	Rotorcraft
RF	Radius to a fix
RMT	Reference mission trajectory
RNAV	Area navigation
RNP	Required navigation performance
ROT	Runway occupancy time
RP	Reference period

RPAS	Remotely-piloted aircraft system
RTCA	Radio technical commission for aeronautics
RTM	Remote tower modules
RTS	Remote tower services
S & M	Sequencing and metering
SAR	Search and rescue
SATCOM	Satellite communications
SBAS	Satellite-based augmentation system
SBT	Shared business trajectory
SDM	SESAR Deployment Manager
SDR	Software defined radio
SES	Single European Sky
SESAR	Single European Sky ATM Research
SID	Standard instrument departure
SJU	SESAR Joint Undertaking
SMO	Standards making organisation
SMR	Surface movement radar
SMT	Shared mission trajectory
SNI	Simultaneous non-interfering
SOA	Service-oriented architecture
SSR	Secondary surveillance radar
STAM	Short-term ATFCM measures
STAR	Standard instrument arrival
STATFOR	EUROCONTROL statistics and forecast service
STCA	Short-term conflict alert
SVS	Synthetic vision system
SWIM	System wide information management
SWIM-TI	SWIM technical infrastructure
TBO	Trajectory based operations
TBS	Time-based separation
TFC	Traffic
TMA	Terminal manoeuvring area
TRN	Terrain reference navigation
TS	Traffic synchronisation
TSAT	Target start approval time
TTA	Target time of arrival
TTO	Target time over
TTOT	Target take-off time
UDPP	User-driven prioritisation process
UHF	Ultra high frequency
UUP	Updated airspace use plan
VFR	Visual flight rules
VHF	Very high frequency
VNAV	Vertical navigation
VoIP	Voice over internet protocol
VOR	VHF omni-range
VSATS	Very small aperture terminals
WAIC	Wireless avionics intra-communication
WAM	Wide area multilateration
WOC	Wing operation centre
WRC	World radiocommunication conference
WX	Weather
XMAN	Cross-border arrival management

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