EUROPEAN ATM MASTER PLAN

Digitalising Europe's Aviation Infrastructure

Executive view

SESAR JOINT UNDERTAKING

founding members

EUROPEAN UNION

EUROCONTROL

2020 edition

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This edition of the European ATM Master Plan
is dedicated to the memory of Stefano Porfiri.
He will be remembered for his warmth and generosity of spirit,
as well as his tireless commitment to SESAR
and air traffic management modernisation in Europe.

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EXECUTIVE SUMMARY

The European ATM Master Plan in a nutshell

Within the framework of the EU aviation strategy and Single European Sky (SES), the European Air Traffic Management (ATM) Master Plan (hereafter referred to as 'the Master Plan') is the main planning tool for ATM modernisation across Europe. It defines the development and deployment priorities needed to deliver the Single European Sky ATM Research (SESAR) vision. The Master Plan is regularly updated, through strong collaboration between all ATM stakeholders, in order to respond to the evolving aviation landscape.

WHY ACT NOW?

Steady increase in conventional traffic

Following the economic crisis of a decade ago, since 2014 Europe has seen a steady return to air traffic growth, which is forecast to continue in the long term. The year 2018 saw an all-time record of 11 million flights in the airspace of the European Civil Aviation Conference, an increase of 4 % on 2017, and the most reliable traffic forecast scenarios anticipate over 15 million flights per year by 2035. In 2018, the average en-route air traffic flow management (ATFM) delay over SES airspace was just under 2 minutes per flight, while the EU-wide performance target for the year was 0.5 minutes. The 2018 average was double the 2017 figure, and, in view of the expected continued growth, all signs are that the delay situation will deteriorate further and dramatically if stringent actions are not taken.

This so-called capacity crunch is also affecting airports: in the absence of bold action, airports will be unable to accommodate approximately 1.5 million flights in 2040, which is equivalent to around 160 million passengers unable to fly ([1]).

Growing environmental concerns

With the growth in air traffic come concerns about its environmental and health impacts. These concerns in Europe and worldwide are prompting the aviation industry to step up its efforts to address the environmental sustainability of air travel to reach the EU's carbon neutral goal by 2050 ([2]). In support of this goal, the SESAR project has prioritised solutions that will gradually contribute to the elimination of environmental inefficiencies due to the underlying aviation infrastructure.

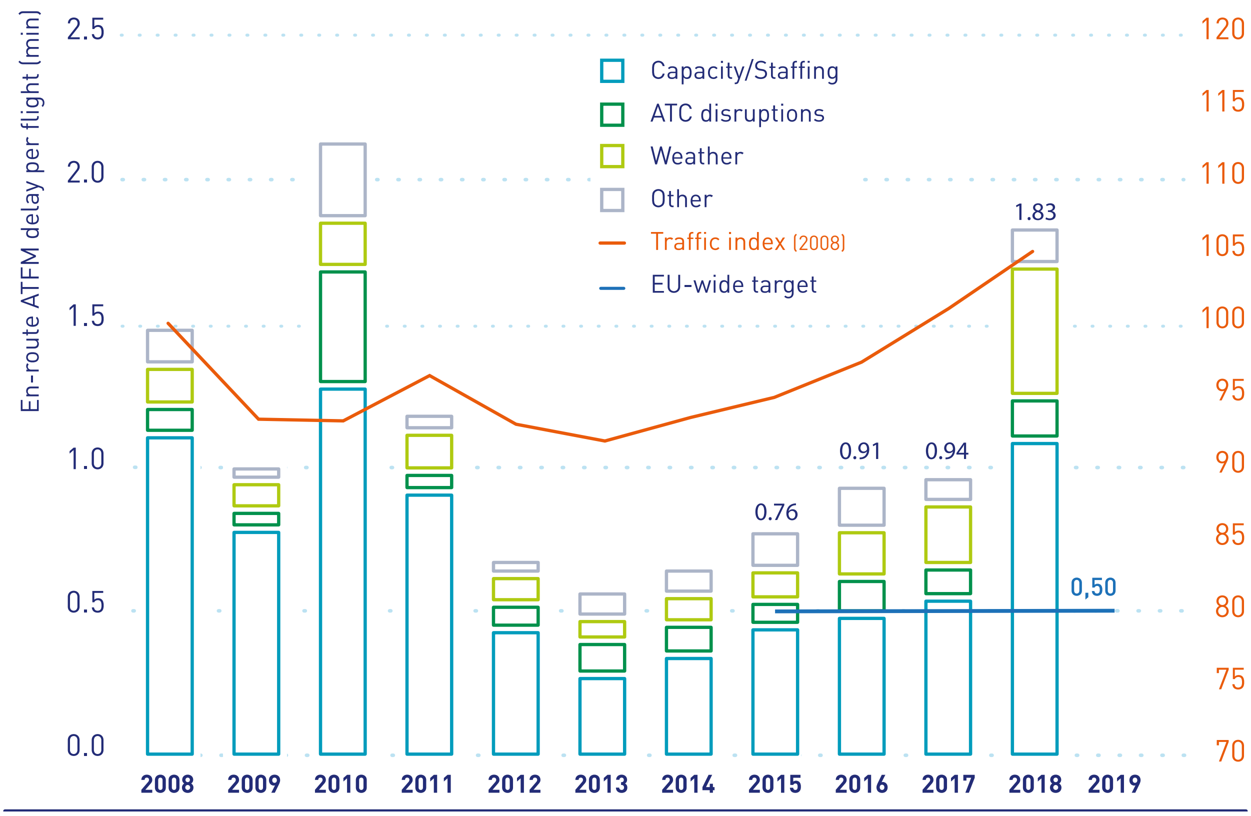
Emergence of new entrants into the airspace

The booming drone industry is creating new markets and huge business

([1]) All figures in this paragraph are extracted from Eurocontrol, *'European aviation in 2040 — challenges of growth'*, 2018 (https://www.eurocontrol.int/articles/challenges-growth).

([2]) *European aviation environmental report 2019*.

AVERAGE EN-ROUTE ATFM DELAY PER FLIGHT



Source: EUROCONTROL, Performance Review Unit

opportunities [3], particularly in terms of urban mobility and service delivery, but it also poses a significant and complex challenge in terms of ATM, given the expected large number and heterogeneous nature of these aerial vehicles. Highly automated vehicles (single-pilot operations, urban air mobility aircraft, cargo drones, etc.) will require new forms of traffic management and air-ground system integration. At the same time, interest is growing again in the potential for operating vehicles at very high altitudes, which will need access to and from the stratosphere via managed airspace. The need for change is becoming even more pressing, as we can already observe the limits of the current system resulting in increasing delays and disruptions. Pressure to optimise trajectories is higher than ever before, and there is a growing need to enable new forms of flight that are attracting a significant share of global investments.

WHAT WILL THE FUTURE OF AVIATION INFRASTRUCTURE LOOK LIKE?

The current European ATM system and network will not be able to accommodate the expected traffic growth and the new challenges without embracing digitalisation at an accelerated pace. This endeavour is fully in line with the vision of the EU aviation strategy [4], which acknowledges SES and SESAR as key drivers of sustainable growth and innovation in air transport.

SESAR's vision: towards a digital European sky

In order to manage future traffic growth safely while mitigating the environmental impact, the SESAR vision is to deliver a fully scalable traffic management system capable of handling growing air traffic, both manned and unmanned. The vision builds on the notion of trajectory-based operations, which

[3] SESAR Joint Undertaking (SJU), *Drones outlook study*, 2016; SJU, *Roadmap for the safe integration of drones into all classes of airspace*, 2018

[4] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — An aviation strategy for Europe (COM(2015) 598 final), Brussels, 7.12.2015.

enable airspace users to fly their preferred flight trajectories, delivering passengers and goods on time to their destinations as cost-efficiently as possible. This will be enabled by a digital transformation of the underlying infrastructure system, characterised by a significant increase in levels of automation and connectivity. The system infrastructure will become more modular and agile, allowing air traffic and data service providers, irrespective of national borders, to plug in their operations where needed, supported by a wider range of services. Airports will be fully integrated into the ATM network, which will facilitate and optimise airspace user operations. The vision will be realised across the entire European aviation network, rather than segmented portions of airspace, as is the case today.

Combining airspace design and technological solutions

Delivering the vision will require changes in the way that technologies are developed and deployed, as well as in the way services are provided. This change in approach builds on the recommendations made in '*A proposal for the future architecture of the European airspace*', developed by the SESAR Joint Undertaking with the support of the Network Manager and delivered to the European Commission in February 2019. Known as the Airspace Architecture Study, the proposal seeks to address the airspace capacity challenge in the medium to long term by combining airspace configuration and design with technologies to decouple service provision from local infrastructure and progressively increase the levels of

collaboration and automation support. The findings and recommendations of the proposal are aligned with and integrated into the Master Plan. The new approach is illustrated in the figure opposite.

Integrating all aerial vehicles, manned and unmanned

The realisation of the vision also depends on the integration of the wide variety of new aerial vehicles accessing the airspace alongside conventional manned aircraft. This is U-space, a framework designed to fast-track the development and deployment of a fully automated drone management system, in particular for but not limited to very low-level airspace. Scalable by design, U-space relies on high levels of autonomy and connectivity in combination with emerging technologies. Alongside U-space is the need to integrate large remotely piloted aircraft systems into manned traffic, with special provisions designed to compensate for the fact that the pilot is not on board the aircraft. The roadmap covering drone integration is incorporated into this edition of the Master Plan.

HOW CLOSE ARE WE TO REALISING THIS VISION?

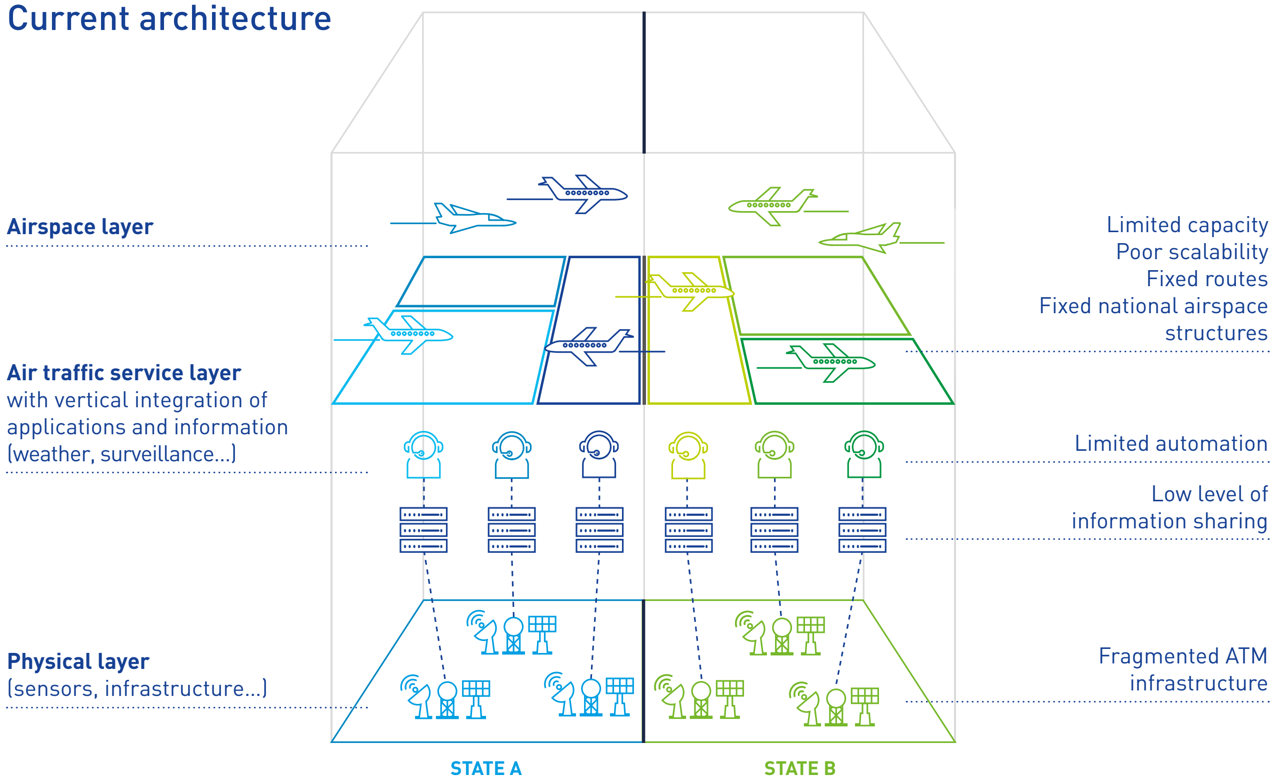
Taking a phased approach

The vision is being realised in four progressive but overlapping phases. This phased approach takes into account that aviation is digitalising rapidly and that the supporting infrastructure needs to evolve based on shorter innovation cycles than in the past.

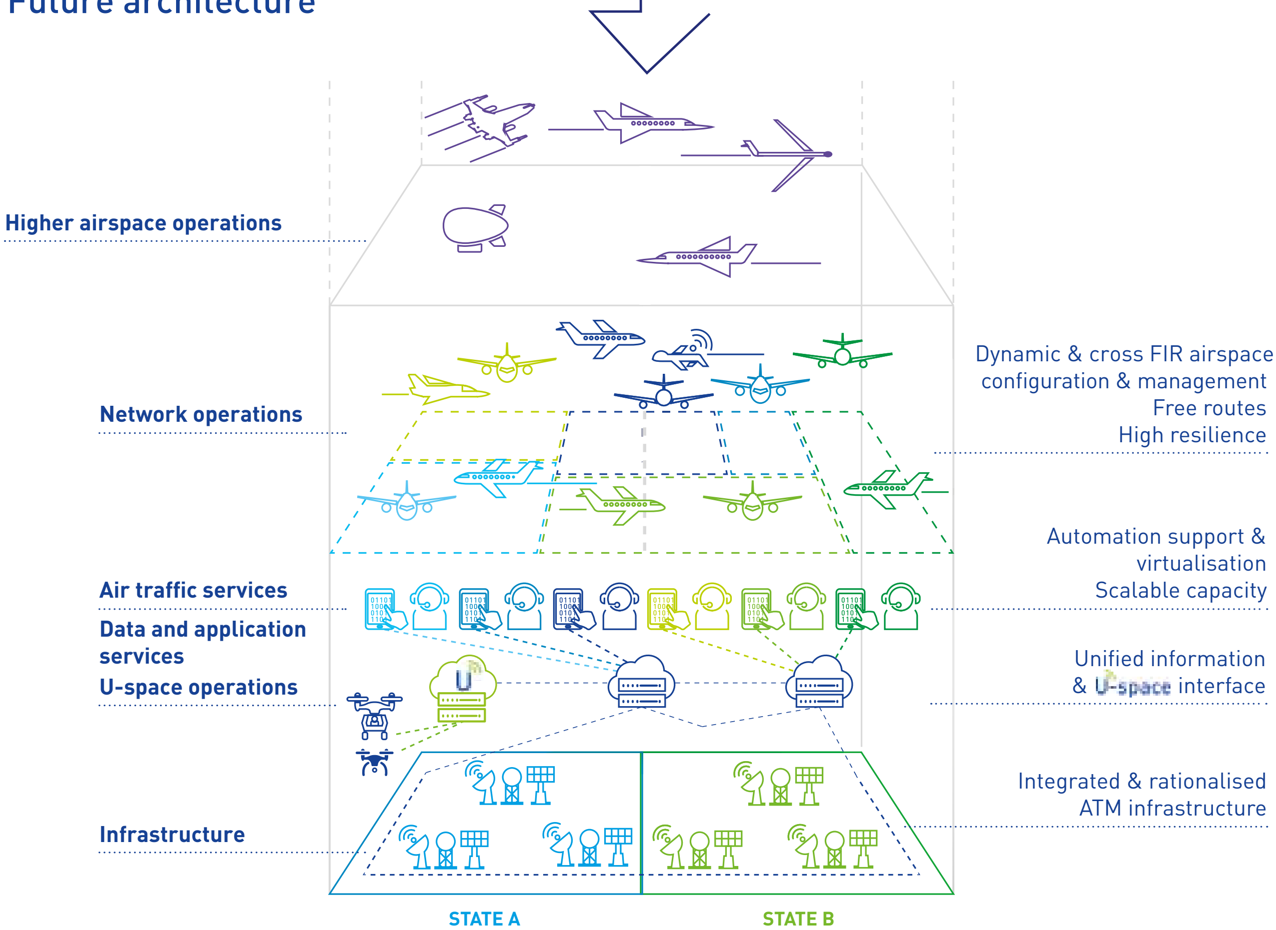
Phase A: address known critical network performance deficiencies by delivering solutions that enhance collaboration between stakeholders, including across state borders and with aircraft, implementing initial system-wide information management, and introducing network capacity and demand balancing measures.

Phase B: efficient services and infrastructure delivery through the launch of first ATM data services, the introduction of cross-border free-route operations, and the integration of advanced airport performance management into the network and the provision of initial U-space services.

Current architecture



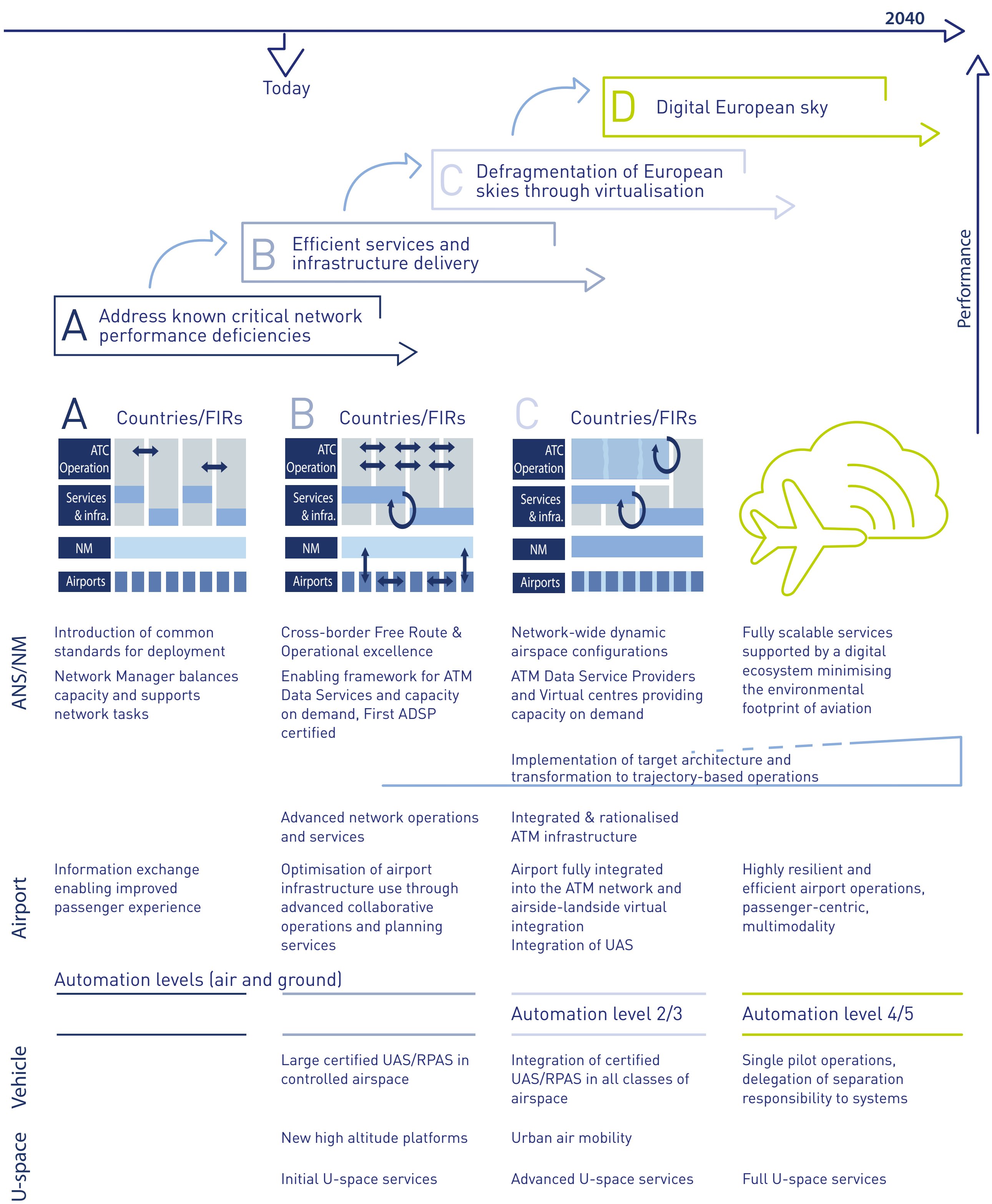
Future architecture



Phase C: defragmentation European skies through virtualisation and dynamic airspace configuration, supported by the gradual introduction of higher levels of automation support, the full integration of airports into ATM at network level and the management of routine drone operations.

Phase D: digital European sky through the delivery of a fully scalable system for manned and unmanned aviation supported by a digital ecosystem, full air-ground system integration, distributed data services, and high levels of automation and connectivity.

FOUR-PHASE APPROACH TO IMPROVEMENTS

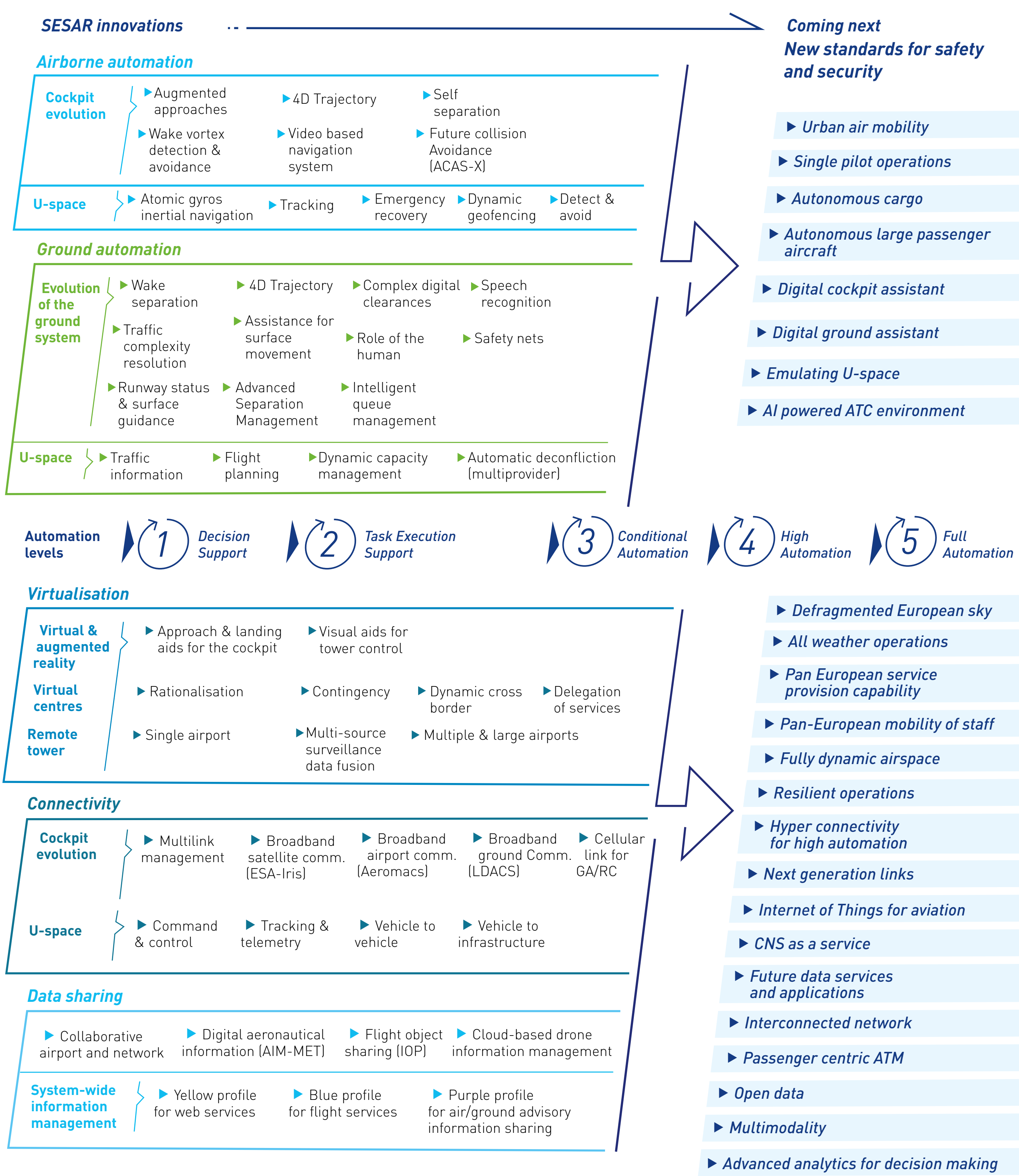


State of play

Steps towards delivering the vision are under way, with the delivery of the first batch of mature SESAR Solutions and the start of synchronised European deployment in 2014 (known as the Pilot Common Project). In addition, local deployments of SESAR Solutions have taken place in parallel (see European ATM Master Plan Level 3 for more information [5]). To date, one third of the SESAR Solutions have been

[5] see: www.ATMMasterPlan.eu

WHAT IS COMING NEXT?



delivered for deployment, while one third are in development and in the pipeline towards deployment; these two thirds will allow the delivery of up to phase C of the vision. The remaining third are those to be undertaken in future research and development to deliver phase D, as illustrated in the 'Coming next' area of the figure.

What is the timeline for the rollout?

The rollout of SESAR Solutions and the delivery of the digital European sky should be complete by 2040 in order to address the challenges faced by aviation infrastructure in Europe and deliver maximum benefits to EU citizens.

Although SESAR has already contributed to shortening the innovation cycle in ATM, achieving the SESAR vision by 2040 will be challenging in the present context and using the present ways of working. In order to complete this transformation, it will therefore be essential to move towards new ways of working within SESAR and a regulatory framework that encourages innovation to enable a further shortening of the innovation cycle. With these changes and strong collective commitment and motivation, it is likely that the transformation can be delivered by 2040 with significant positive consequences for EU growth, EU citizens, and the attractiveness and sustainability of the aviation sector at large.

WHAT ARE THE EXPECTED BENEFITS?

Delivering the digital European sky represents tremendous value potential for every stakeholder in the aviation value chain; it will also significantly benefit the

European economy and society in general at relatively small investment cost.

It is estimated that, by 2040, the value of all the direct and indirect benefits would amount to EUR 80 billion in annual recurring benefits for manned and unmanned aviation. Realising the benefits will largely depend on the ability of the sector to create the conditions to shorten the innovation life cycle for infrastructure modernisation. If these conditions are not created, the transformation is likely to be completed only by 2050, with negative implications for the environment, jobs and growth in Europe.

More critically, these benefits also rely on the scaling up and rationalisation of investments in infrastructure amounting to a total investment need in the range of EUR 30 billion to EUR 40 billion in the period up to 2040, covering needs in relation to both manned and unmanned aviation. If innovation cycles are not shortened, these investments will need to be significantly higher, reaching EUR 60 billion, as legacy and new system components would have to co-exist and be maintained during a longer transition period.

Altogether these investments represent a very small portion (less than 5 %) of the value at stake, considering also the significant investments that will be made in the next 20 years by airspace users and new entrants to introduce new aircraft into the skies, amounting to several hundreds of trillions of euros.

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Aviation is an important driver of economic growth, jobs and trade, with a major impact on the lives and mobility of European citizens ([6]). The Single European Sky (SES) initiative aims to achieve more sustainable and better performing aviation in Europe ([7]), and Single European Sky Air Traffic Management (ATM) Research (SESAR) is the technological pillar of the SES initiative.

A performance-driven, innovative and state-of-the-art ATM system is recognised as a critical element for achieving greater connectivity, as well as safe and predictable air travel for passengers, while ensuring the environmental sustainability of the aviation sector in Europe. That is why in 2004 the SESAR project ([8]) was set up to modernise and harmonise ATM systems through the definition, development and deployment of a new generation of innovative operational and technological solutions compliant with the SES objectives and taking due care of the human dimension.

In line with the goals set out in *Flightpath 2050* ([9]) and the EU's aviation strategy ([10]), the SESAR vision, driving the European ATM Master Plan (hereafter referred to as 'the Master Plan'), is to deliver an ATM system for Europe that is fit for the 21st century and capable of handling the growth and diversity of traffic safely and efficiently while improving environmental performance, thereby contributing to the SES high-level goals adopted in 2005 ([11]).

([6]) According to the European Commission, the aviation industry employs around 1.4 million people and supports between 4.8 million and 5.5 million jobs. Aviation contributes EUR 110 billion to the EU's gross domestic product (GDP).

([7]) European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — Single European Sky II: towards more sustainable and better performing aviation (COM(2008) 389 final), Brussels, 25.6.2008.

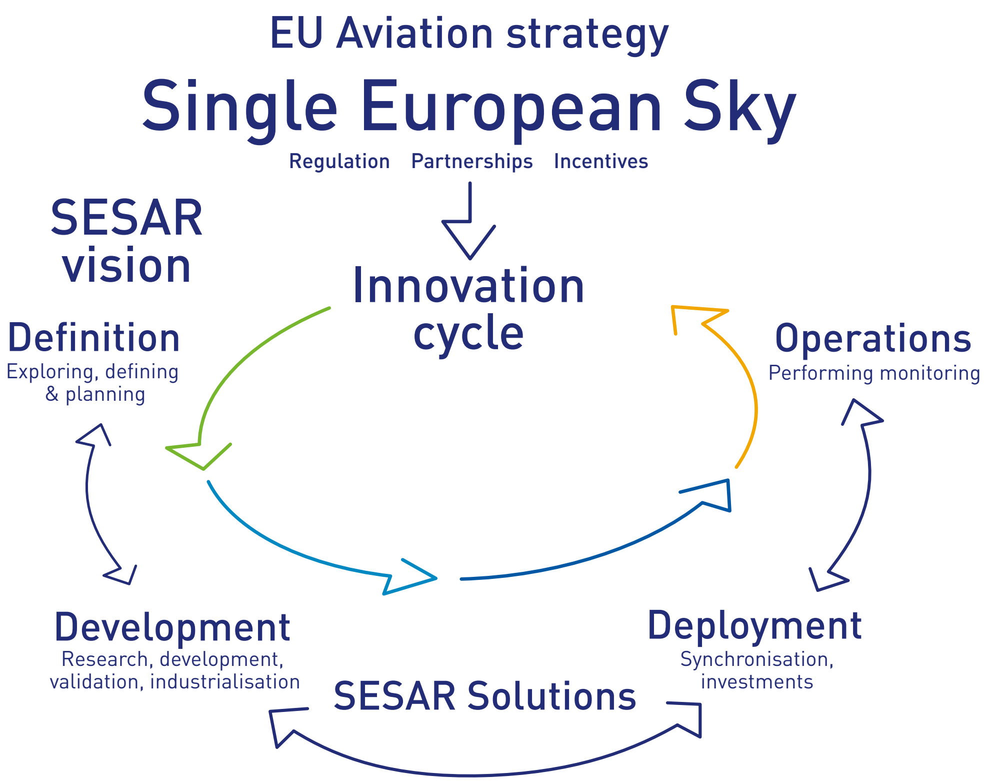
([8]) The SESAR project is the vast European ATM modernisation initiative, also described as the SES 'technological pillar', broken down into three phases: definition, development and deployment. The research and development (R&D) phase is organised as a programme. The SESAR 1 Programme was closed at the end of 2016, and the current R&D Programme is SESAR 2020, which is split into Solutions and transversal projects. This is further detailed in this section.

([9]) European Commission, *Flightpath 2050 — Europe's vision for aviation: report of the High Level Group on Aviation Research*, Publications Office of the European Union, Luxembourg, 2011 (https://ec.europa.eu/transport/sites/transport/files/modes/air/doc/flightpath2050.pdf).

([10]) https://ec.europa.eu/transport/modes/air/aviation-strategy_en

([11]) The goals are to improve safety by a factor of 10; to enable a threefold increase in capacity that will also reduce delays both on the ground and in the air; to enable a 10 % reduction in the effects flights have on the environment; and to provide ATM services to airspace users at a unit cost of at least 50 % less (European Commission, Communication from the Commission to the Council and to the European Parliament — The Air Traffic Management Master Plan (the ATM Master Plan) (COM(2008) 750 final), Brussels, 14.11.2008).

FIGURE 1. **THE SESAR PROJECT'S INNOVATION CYCLE**



1.1 A POLICY-DRIVEN PROJECT

As acknowledged by the EU's aviation strategy, innovation is a key enabler for the sustainability of Europe's air transport sector, offering greater mobility and connectivity for passengers and more opportunities for business growth. By investing in innovation, Europe remains competitive and a leader in the global market, delivering state-of-the-art technologies and setting high standards in terms of safety and performance worldwide. The SESAR innovation cycle has been put in place in support of the EU's aviation strategy and the SES initiative; it pools the resources and expertise of all ATM stakeholders in a coordinated way in order to define, develop and deploy solutions that meet Europe's policy objectives on aviation and air transport.

1.1.1 Definition

The Master Plan defines the vision and objectives of the SESAR project. It is an evolving document intended to ensure that the priorities determined and commitments made for SESAR development and deployment activities remain strongly connected to EU policy priorities.

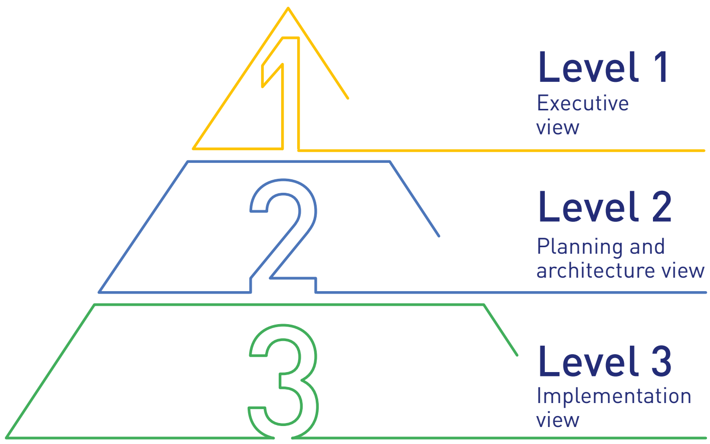
The content of the Master Plan is organised into three levels, as shown in **FIGURE 2**, to enable stakeholders to access information at the level of detail that is most relevant to their area of interest.

This document presents the executive view (Level 1). It outlines the SESAR vision in Chapter 2; performance ambitions associated with the vision in Chapter 3; priorities (essential operational changes) in Chapter 4; the deployment roadmap (how and when the SESAR vision will be deployed) in Chapter 5; the impact assessment (benefits and investments needs) in Chapter 6; and the main risks and mitigation actions associated with the execution of the ATM Master Plan in Chapter 7.

The intended readership for Level 1 is policy- and executive-level stakeholders.

Levels 2 and 3 of the Master Plan provide more detail on operational changes and related elements, and therefore the target

FIGURE 2. **THE THREE LEVELS OF THE EUROPEAN ATM MASTER PLAN**



audience comprises experts among those same stakeholders.

Level 2 is the planning view for SESAR development activities.

Level 3 is the planning view for SESAR deployment activities.

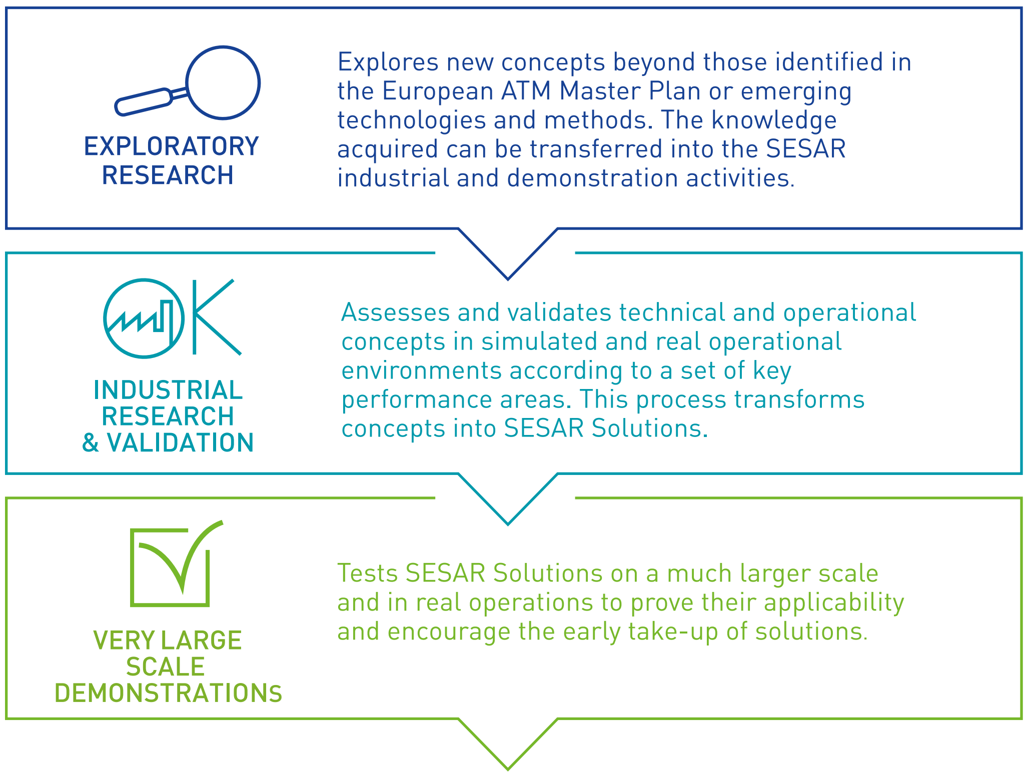
All three levels of the Master Plan are available for consultation interactively, via the ATM Master Plan portal ([12]). A 'drill-down' capability provides access to related information in the development and deployment views (Levels 2 and 3 respectively).

The Master Plan provides the basis for reporting by the stakeholders and key institutions on the execution of SESAR.

1.1.2 Development

SESAR has created a pipeline through which promising ideas are explored and then moved out of the 'lab' and into real

([12]) www.atmmasterplan.eu



operations. The pipeline consists of three distinct strands.

SESAR Solutions are the main output of the SESAR development activities. They are new or improved operational procedures or technologies that aim to contribute to the modernisation of the European and global ATM systems. These solutions address all parts of the ATM value chain, integrating operations on the ground and in the air, as well as the underlying system architecture and technological enablers, which are validated in real day-to-day operations.

1.1.3 Deployment

When a SESAR Solution reaches maturity and is ready for implementation, it is delivered to the aviation community for industrialisation and subsequent deployment. This deployment can be voluntary or mandated, local or coordinated across the network under EU regulatory frameworks, and may be supported by EU funding. Local deployment activities are decided based on specific, localised business cases (e.g. in the case of remote towers) or through investors' collective commitment recorded at EU level through the Master Plan Level 3 processes. Coordinated deployment may be opted for where the implementation of a change is critical to the performance of the European network. The first wave of Europe-wide coordinated deployment started in 2014 and was supported by a regulatory framework and funding from the EU; this deployment work was carried out primarily through the Pilot Common Project (PCP) and the associated deployment programme.

1.2 EVOLVING WITH THE TIMES

The Master Plan represents a snapshot in time and is updated on an annual basis. A major update is performed approximately every 2-3 years ([13]), through a collective 'update campaign' process involving all stakeholder categories and key aviation institutions ([14]).

Reflecting the changing landscape of aviation, this fourth edition, aims to achieve the following.

- **Address the new challenges, tackling the steady increase in traffic demand from both manned and also now unmanned aviation, and enabling the emergence of new business models, while supporting the sustainability of aviation.** The 2015 edition of the Master Plan reflected the need to focus on those ATM modernisation efforts that could bring the greatest cost efficiency in response to the economic crisis. With the recent return to steady traffic growth, forecast to continue in the long term ([15]), the focus now is on addressing the so-called capacity crunch while maintaining safety and mitigating environmental impact. The year 2018 saw an all-time record of 11 011 434 flights in the network, an increase of 3.8 % on 2017. En-route air traffic flow management (ATFM) delays increased to 1.83 minutes per flight, compared with the EU-wide performance target of 0.5 minutes. This yearly capacity performance target has not been met since 2014, an indication of the inability of

([13]) The first edition of the Master Plan was derived from the SESAR Master Plan and issued in May 2008 as one of the six main deliverables from the SESAR definition phase, as agreed by all major European aviation stakeholders. It was endorsed by the Transport Council of the European Union on 30 March 2009. Although not legally binding, the endorsement represented a clear political commitment to the SESAR project and an acknowledgement of the importance of the Master Plan. Two further editions of the Master Plan were published in 2012 and 2015 respectively (see https://ec.europa.eu/transport/modes/air/sesar/european_atm_en).

([14]) 'All stakeholder categories' means air navigation service providers, airspace users and airports; the key players and institutions in European aviation are the European Commission, Eurocontrol, the European Aviation Safety Agency (EASA), the European Organisation for Civil Aviation Equipment, the European Defence Agency, the Network Manager, the SESAR Deployment Manager, the relevant ground and air manufacturing industries, and professional staff associations.

([15]) Eurocontrol, *European aviation in 2040 — challenges of growth*, 2018 (https://www.eurocontrol.int/articles/challenges-growth).

the system to cope with the situation ([16]). The average delay in 2018 was double that in 2017 and the situation is expected to deteriorate further in the coming years if stringent actions are not taken. The increased number of flights and delays also meant that CO_2 emissions grew by 5.2 % during the same period. The capacity crunch is not just in the skies; it is also affecting airports. It is estimated that in the absence of bold action the 'airport bottleneck' may lead to 1.5 million unaccommodated flights in 2040, equivalent to around 160 million passengers unable to fly. These challenges must be addressed. In addition, the emergence of rapidly growing drone traffic (and also the recent emergence of interest in very high-altitude aerial vehicle operations) is perceived as both a challenge (safely and efficiently integrating these new aerial vehicles into the controlled and uncontrolled airspace) and an opportunity (drones and the relevant services can serve as a testbed, for example for connectivity and virtualisation technologies that can then be applied to manned aviation).

- **Seize new opportunities, accelerating the digital transformation of the aviation infrastructure to accommodate aerial vehicles, which are set to become more autonomous, more connected and more intelligent.** Digital transformation is widely recognised today as a driving force behind innovation, business growth and improved well-being for citizens. This is also true for the aviation industry, which is embracing technological advances to respond to increasing demand for travel, as well as to cater for new airspace users seeking access to Europe's skies. New technology can improve the efficiency of airspace, ensuring better environmental performance

([16]) *PRB Annual Monitoring Report 2017*. (https://webgate.ec.europa.eu/eusinglesky/system/files/ged/2017-rp2-prb-monitoring-report-volume-3_safety_v1.1_0.pdf) and enhancing safety. The aviation industry has shown its commitment to this digital transformation with a joint industry declaration, 'Towards the digital European sky'([17]), published in November 2017 at a high-level event in Tallinn against the backdrop of the European Digital Transport Days , marking the start of the update campaign leading to the delivery of the present edition of the Master Plan.

- **Take stock of, and acknowledge, the overall progress achieved in the SESAR project (closure of the SESAR 1 programme in 2016, launch in 2017 of the SESAR 2020 programme, first concrete results from SESAR deployment).** This progress is outlined in Chapters 4 and 5, where the mature technology that is in deployment or in the pipeline towards deployment is described. It should be noted that SESAR has not delivered against a 'moving target', as the four phases for the delivery of the SESAR vision have remained unchanged from the last version of the Master Plan: the SESAR 2020 programme has the ambition of delivering phase C of this vision by the unchanged date of 2035, making it possible to reach by the same target date the performance ambitions detailed in Chapter 3 and also supporting the phased implementation of the Airspace Architecture Study.

1.3 NEW ELEMENTS IN THIS EDITION

This latest edition incorporates several supporting and complementary studies and analyses.

- **A proposal on the future architecture of the European airspace** was developed by the SESAR Joint Undertaking (SJU) ([18]), with the support of the Network Manager, and delivered to the European Commission in February 2019. Known as the Airspace Architecture Study, the proposal seeks to address the airspace capacity challenge in the short to long term by combining airspace configuration and design with technologies to decouple service provision from local infrastructure and progressively increase the levels of collaboration and automation support. The intention is to ensure that airspace is optimised according to operational needs, regardless of flight information regions (FIRs) or national boundaries. The content, approach and key milestones of the study are fully synchronised with, and make use of, the technology that is being developed within the SESAR programme, combined with operational improvements. This is made clear throughout this edition of the Master Plan, in which interrelations between the supporting technological roadmaps are duly identified and assessed to highlight the critical path, in terms of dependencies and timelines, to achieving the defragmentation of European skies through virtualisation and the free flow of data among trusted users across the network. The sovereignty, responsibility and liability issues are important aspects that are addressed by the European Commission in a specific study.

- **The roadmap for the safe integration of drones into all classes of airspace** was adopted by the SESAR Administrative Board in March 2018 ([19]). It outlines which drone-related research and development

([17]) Towards the Digital European Sky. A Joint Industry Declaration. (https://www.sesarju.eu/sites/default/files/documents/reports/Joint%20Declaration%20-%20Towards%20the%20Digital%20European%20Sky.pdf)

([18]) https://www.sesarju.eu/node/3253

([19]) SJU, European ATM Master Plan — roadmap for the safe integration of drones into all classes of airspace (https://www.sesarju.eu/node/2993)

(R&D) activities should be prioritised in order to support the expansion of the drone market and achieve the smooth, safe and fair integration of these new aircraft systems into the European airspace. This includes U-space, a framework designed to fast-track the development and implementation of a drone management system, in particular for but not limited to very low-level (VLL) airspace, as well as provisions to integrate large remotely piloted aircraft systems (RPAS) into manned traffic. The key elements of this roadmap have been incorporated into this edition of the Master Plan.

- **A more integrated air-ground roadmap to enable improvements in aviation infrastructure and in particular a move towards performance-oriented communications, navigation and surveillance (CNS) infrastructure** was developed. It details the capabilities that make up the future CNS infrastructure and services, as well as steps to integrate and rationalise CNS systems and technologies in order to increase their performance, in terms of costs, coverage and spectrum use. The roadmap provides a timeline, aligned with the four phases of the Master Plan, for the rollout of the future CNS infrastructure.

- **The definition of phase D of Master Plan, for the delivery by 2040 of a fully scalable system able to handle both manned and unmanned aviation in line with the joint industry declaration 'Towards the digital European sky'.** This includes the high-level identification of related future R&D and investment needs. Linked to this, an ATM automation model that mirrors the five-level model from the Society of Automotive Engineers (ranging from Level 0, 'no automation', to Level 5, 'full automation') was developed. The model illustrates the level of automation anticipated for each phase of the Master Plan.

- **An updated assessment of the macroeconomic impact of SESAR**, considering the broader impact of changes or costs related to the modernisation of aviation infrastructure. This includes an assessment of passenger benefits and other impacts on society driven by SESAR (e.g. environmental impacts).

1.4 ACKNOWLEDGEMENTS

The scale and complex nature of ATM in Europe means that no one stakeholder can fix it; it can be done only through effective collaboration. Like previous editions, this latest Master Plan was produced with the close involvement of all key players in the aviation world: beyond the continued involvement of all stakeholder categories (air navigation service providers (ANSPs), the Network Manager (NM), airspace users (AUs), airports, ground and airborne manufacturing industries, and professional staff associations), the European Aviation Safety Agency (EASA) has been closely involved throughout the update campaign process, and explicit links and cross-references have been made between the Master Plan and the European Plan for Aviation Safety (EPAS). The involvement of the European Organisation for Civil Aviation Equipment (EUROCAE) made it possible to identify standardisation needs.

The European Defence Agency (EDA) has been present and involved throughout the update process, and several dedicated workshops have been held with the military community. Enhanced civil-military collaboration, aimed at fulfilling civil and military operational objectives safely and efficiently, was achieved through the involvement of the relevant experts from the EDA and Eurocontrol. The NM was also involved at every stage to ensure consistency between the network strategy plan and the Master Plan. The contribution of the SESAR Deployment Manager (SDM) made a more robust link with coordinated deployment activities possible. SESAR's Scientific Committee was consulted to ensure the quality of the approach to the digitalisation and automation elements of the Master Plan.

Repeated contact and coordination with the Performance Review Body resulted in coordination of efforts between the technology and performance pillars of the SES to ensure the readability of the SESAR performance ambitions by the SES performance scheme. Efforts were also made to make more visible and explicit the link between the Master Plan's priorities and key objectives and the EU's aviation strategy.

THE SESAR VISION

By 2040, an increasing number and variety of air vehicles will be taking to Europe's skies. The SESAR vision aims to deliver a resilient and fully scalable ATM system capable of handling growing air traffic made up of a diverse range of manned and unmanned air vehicles in all classes of airspace, in a safe, secure, sustainable manner.

The vision builds on the SESAR target concept and primarily on the notion of trajectory-based operations (TBO), which enable airspace users to fly their preferred flight trajectories, delivering passengers and goods on time to their destinations as cost-efficiently as possible. This will be enabled by a new architecture referred to as the 'digital European sky', in which resources (on the ground and in the air) are connected and optimised across the network and irrespective of altitude (up to and including super-high-altitude operations), class of airspace or aircraft performance (manned or unmanned), leveraging modern technology through a data-rich and cyber-secure connected digital ecosystem. In this environment, service providers will be

THE DIGITAL EUROPEAN SKY

By 2040, increasing numbers of aerial vehicles ([1]) (conventional aircraft and unmanned aircraft, such as drones) will be taking to Europe's skies, operating seamlessly and safely in all environments and classes of airspace. Trajectory-based free-route operations will enable airspace users (civil and military) to better plan and execute their business and mission trajectories ([2]) within an optimised airspace configuration that meets safety, security and environmental performance targets and stakeholder needs. The system infrastructure will progressively evolve with the adoption of advanced digital technologies, allowing civil and military ANSPs and the Network Manager to provide their services in a cost-efficient and effective way irrespective of national borders, supported by secure information services. Airports and other operational sites (e.g. landing sites for rotorcraft and drones) will be fully integrated at the network level, which will facilitate and optimise airspace user operations in all weather conditions. ATM will progressively evolve into a data ecosystem supported by a service-oriented architecture enabling the virtual defragmentation of European skies. Innovative technologies and operational concepts will support a reduction in fuel and emissions while also mitigating noise impact, in support of the EU's policy of transforming aviation into a climate-neutral industry. Performance-based operations will be fully implemented across Europe, allowing service providers to collaborate and operate as if they were one organisation with both airspace and service provision optimised according to traffic patterns. Mobility as a service will take intermodality to the next level, connecting many modes of transport, for people and goods, in seamless door-to-door services.

([1]) Traditional aircraft will be complemented by new entrants such as very low-level drones, military medium-altitude long-endurance unmanned aircraft systems, automated air taxis, super-high-altitude (FL600+) operating aircraft, next generation supersonic aircraft and electrically propelled aircraft.

([2]) Meaning that aircraft and drones can fly their preferred trajectories.

able to collaborate and operate as if they were one organisation with both airspace and service provision optimised according to traffic patterns. This architecture is also more compatible with the overall global vision for a more profound evolution of core ATM capabilities driven by new forms of traffic (drones and super-high-altitude operations).

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, and take account of parallel industrial evolutions. With this in mind, the SESAR vision embraces the entire ATM system, offering improvements at every stage of the flight.

2.1.1 Enabling high network capacity and resilience

The future airspace will be fully optimised according to network flows, making maximum use of cross-FIR cooperation. Supported by progressively higher levels of automation and common ATM data services, the system will be able to use resources more efficiently, responding to disruptions and changing demand with greater flexibility and resilience. The introduction of service-oriented architectures — relying on vertical and geographical decoupling of services along with new technologies, such as virtual centres associated with a sector-independent air traffic services (ATS) framework — will enable dynamic and shared management of airspace and remote provision of ATS, meaning that sectors can be dynamically modified based on demand and airspace available and managed by the most appropriate area control centre. Moreover, flight-centric operations may mean that ATS methods gradually evolve from the management of pieces of airspace (sectors) to the management of the trajectory of flights across a larger portion of airspace, thus enabling increased flexibility. Air traffic flow and capacity management (ATFCM) will evolve to enable the management of complete traffic flows in the network in a more collaborative and dynamic manner, with the increased involvement of airspace users.

2.1.2 Improved flight trajectories, minimising the environmental footprint of aviation

By taking a holistic view of the trajectory from beginning to end, the TBO concept will enable airspace users to operate their preferred trajectory from gate to gate, in order to satisfy their business and operational needs, for example through 4D trajectory optimisation during the planning and execution phases. TBO and 4D are enabled thanks to the sharing of the same aeronautical, weather and 4D trajectory information via ground-ground and air-ground system-wide information management (SWIM) communications. TBO will bring increased predictability, enabling a reduction in buffers and optimisation of capacity and resources. Airspace configuration will be dynamically adjusted in response to capacity and demand needs and using fully developed civil-military collaboration. By optimising aircraft trajectories, TBO also supports greater fuel efficiency. Its benefits will be further increased when combined with solutions such as continuous descent and climb, which will reduce both emissions and noise as well as, possibly, contrail formation. Looking further into the future, innovative technologies and concepts, such as new aerial vehicles using hybrid propulsion and solar energy, will contribute to mitigating aviation's environmental footprint.

2.1.3 Improved airport performance and access

Optimal use of available airport capacity [20] relies on technologies and solutions allowing airports to operate efficiently in periods of high traffic density and extend

[20] Airport operations and maximum airport capacities could become more and more constrained by local, environmentally driven regulations.

periods of operating at maximum capacity including under bad weather conditions. This will be achieved by implementing enhanced runway throughput capabilities, safety nets, and more accurate navigation and routing tools as well as through enhanced planning to achieve higher predictability. New approach procedures will increase operational flexibility and improve access to airports even with limited ground navigation infrastructure. Solutions for remote tower services will not only enable operational coverage to be extended at low- and medium-traffic airports but also have safety and operational efficiency benefits for tower operations. Airport operations will be further integrated with network operations and airspace user operations (e.g. through the user-driven prioritisation process (UDPP)). Better performance prediction will be possible thanks to big data analytics and artificial intelligence (AI). The total airport management (TAM) concept is one example of how to implement the Ground Coordinator at airports in order to improve predictability and punctuality and to contribute to better passengers' experience. Safety on and around the runway will increase thanks to supporting tools and alert systems for air traffic control officers (ATCOs) and pilots preventing runway incursions and excursions as well as collisions on the airport surface. On-board enhanced vision systems will increase access to regional and smaller airports, maintaining or even increasing the safety of operations.

The digital transformation of airports will allow seamless passenger processes and improve landside predictability.

2.1.4 Enabling greater airborne automation

Advances in technologies, as well as capabilities inherent to new unmanned aerial vehicles, will pave the way for higher levels of airborne automation. This will be facilitated by the development of an enabling framework for the integration and management of drones (through U-space)[21] and larger RPAS alongside traditional manned aviation operations. At the same time, innovative traffic management solutions will be developed in order to enable greater levels of autonomy and connectivity in manned aviation. Airframes for commercial passenger transport will move from the current large aircraft with two crew members in the cockpit to a single crew member in the cockpit, that is, single-

[21] The progressive deployment of U-space is envisaged in an incremental manner, moving from U1 (U-space foundation services) to U2 (U-space initial services), U3 (U-space advanced services) and U4 (U-space full services). Each new phase will introduce a new set of services while including an upgraded version of the services already existing in the previous phase.

pilot operations (SPO), paving the way for fully autonomous flights. Flights above FL660 (66 000 ft) will also be integrated, with entry and exit procedures through segregated or non-segregated airspace. These innovative airborne research concepts, when confirmed, will feed into and steer ATM research, first exploratory and then industrial. All these different environments will converge towards an integrated ATM in which manned and unmanned aerial vehicles will operate in a seamless and safe environment using common infrastructure and services. All of this will enable the growth of the sector, particularly with regard to the use of large certified unmanned aircraft systems (UAS) for cargo and other civil operations, air taxis and smaller drones for a host of services (parcel delivery, medical emergencies, etc.).

2.1.5 Improved air navigation services productivity

Air navigation services (ANS) productivity will improve thanks to the introduction of increased levels of automation support in air traffic control (ATC), the move from voice to data communications, and better connectivity and information sharing between ground systems. This means that controllers will perform fewer manual and repetitive tasks, since these will be automated and delegated to the system, allowing controllers to concentrate on more complex work. At the same time, new capabilities will be introduced to enhance the interface between air and ground and enable data exchange, as well as separation management. These enhancements will mean that the system will be more scalable to meet growing demand. ANS productivity will also increase thanks to the shift to a new ATM service delivery landscape. ATM data service providers (ADSPs) will provide the data and applications required to provide ATS. This will enable capacity on demand — more dynamic delegation of the provision of ATS to an alternative centre with spare capacity — and will result in a substantial improvement in ANS operations and productivity.

2.1.6 Optimal use of air navigation services infrastructure and use of scarce resources

The move from physical assets to services, as well as standardisation between systems, will result in a rationalised aviation infrastructure. This is especially the case for CNS, which will rely on more integrated solutions, increased civil-military synergies, and combined ground-based and satellite-based services. This rationalisation and integrated approach to CNS will result in a more efficient use and long-term availability of spectrum. Similarly, the virtualisation of ANS and sharing of data services will enable the delivery of 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. As a result, ANSPs will have leaner, more modular and scalable systems that are easier to upgrade and more interoperable. Because of this, the system will become more resilient to unexpected traffic downturns or rapid returns to growth.

2.1.7 Increased global interoperability and enhanced collaboration

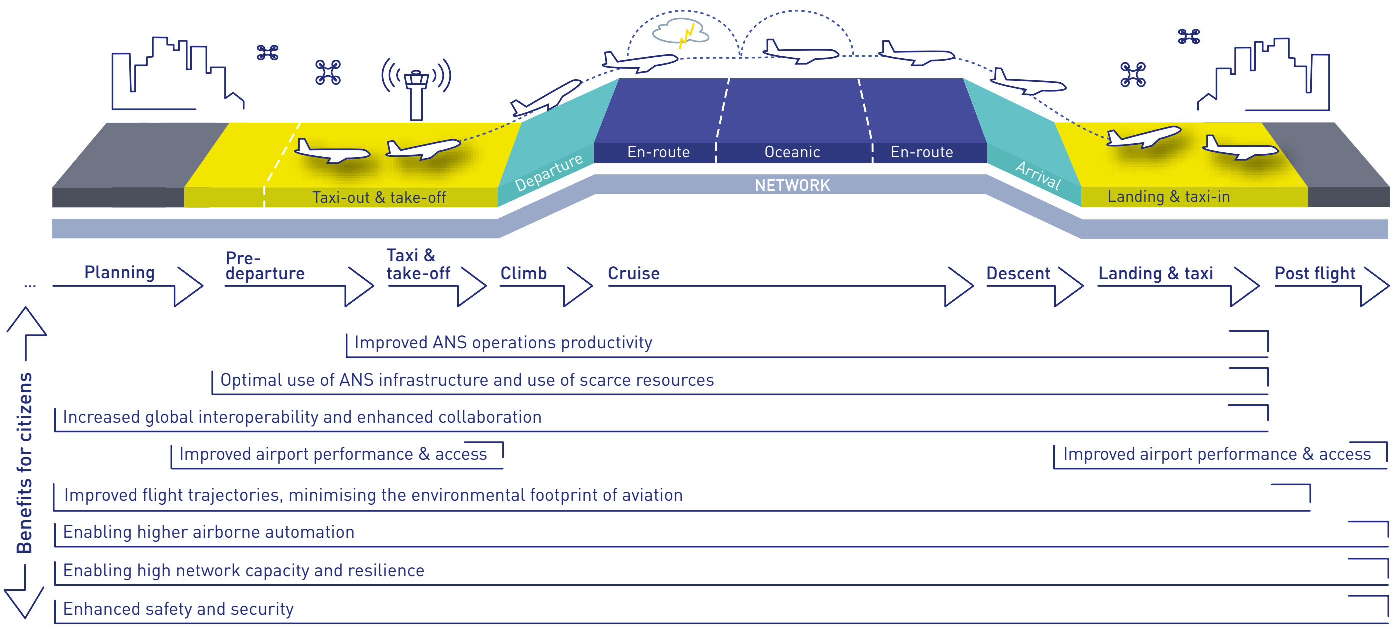
The exchange of trajectory, weather and aeronautical information made possible through information management, supported by SWIM, will enhance collaborative decision-making at network and global levels. Global interoperability will be improved through standardised interfaces for ATM information exchanges, allowing seamless ATM operations for all operational stakeholders.

Sophisticated algorithms and forecast models capable of mining historical data for trends and providing real-time information (big data management) will support further efficient and effective collaborative decision-making involving all relevant parties. These capabilities will be especially important in view of the forecast increase in extreme weather phenomena, which may cause severe local and network-wide disruptions. AI capabilities that combine weather, flight, airport and other transport modality information will deliver insights and opportunities to the established operational actors and to many emerging specialised service providers, focusing on value for the passenger and other end-users.

2.1.8 Enhanced safety and security

The expected increase in automation support will enable the management of the expected growing traffic and variety of aerial vehicles accessing the airspace at the same if not higher levels of safety than today. The widespread use of enhanced ground-based and airborne safety nets in all phases of flight, including on the airport surface, and new safety tools attached to drone operations (geo-fencing and self-separation) will ensure that the future system's contribution to aviation safety is maximised. The system will be defined and developed collaboratively by civil and military stakeholders to ensure trust, cyber-resilience and continuity of operations.

FIGURE 3. **IMPROVEMENTS AT EVERY STAGE OF THE FLIGHT**



2.2 EMBRACING THE DIGITAL TRANSFORMATION OF AVIATION

Digital transformation is not a goal in itself but a means of accelerating the rollout of the SESAR vision. The desired change is profound and goes far beyond the narrow understanding of 'going paperless' or 'replacing analogue with digital'. A 'digitally transformed aviation' will use targeted data and information through automated and connected solutions to improve the overall performance of the system from safety, efficiency and cost perspectives. Aviation will take full advantage of advanced digital technologies to generate new services and optimise current ones while delivering a better experience and benefits to all stakeholders.

Considering the fast pace of technological development outside ATM and the amount of high-risk/high-gain research that could be undertaken in the digital sector (autonomy, AI, fast prototyping, etc.), there is a need for an agile and open approach to collaboration, together with greater coordination, to keep pace and reduce time to market.

The strategy for digitalising European ATM responds to the need, expressed in the EU's aviation strategy, to digitalise Europe's aviation infrastructure and respond to Europe's digital single market strategy ([22]). The future European society and economy will build strongly on increased digitalisation. The ATM industry cannot fall behind and must consolidate its position at the forefront of innovation with a global perspective given the significant potential value for the European economy and citizens (see Chapter 6).

Digitalisation is a transversal topic affecting the full width of ATM, from concept of operations to service provision, from safety-critical systems to passenger travel experience. Therefore, progress in this field must be visible.

The digital single market strategy defines the Digital Economy and Society Index

([22]) European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — A digital single market strategy for Europe (COM(2015) 192 final)., Brussels, 6.5.2015.

(DESI) [23]. It is a composite index that summarises relevant indicators on Europe's digital performance and tracks trends in EU Member States' digital competitiveness. The DESI indicator is a broad societal index that, so far, does not provide details on specific branches of industry. Consequently, to demonstrate alignment between the SESAR project and the digital single market goals, this Master Plan includes a proposal for an ATM digitalisation index (see Annex D) that, by analogy with the DESI, could be used in the years to come to illustrate the uptake of digitalisation by the European ATM industry. The expectation is that higher scores on this index will indicate an improvement in ATM performance and an increase in the economic potential generated by the European ATM industry.

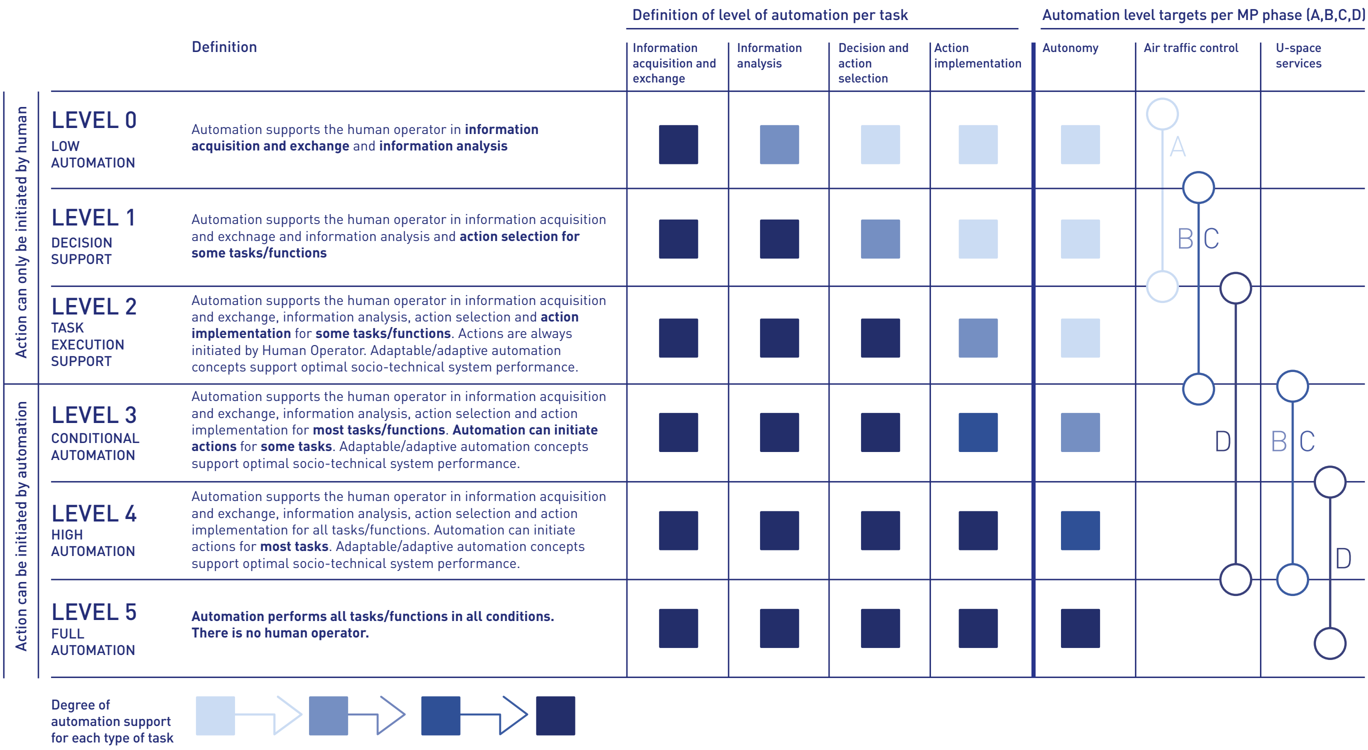
FIGURE 4 introduces an automation model for ATC based on the classic levels of automation taxonomy model used by human performance and safety experts in the SESAR programme. It mirrors the five-level model from the Society of Automotive Engineers (ranging from Level 0, 'low automation', to Level 5, 'full automation') [24]. It presents a simplified view of the overall level of automation in each of the ATM Master Plan phases (A to D) in two different areas: ATC and U-space services. It highlights the steps envisaged towards the profound digital transformation outlined in the Master Plan.

The progress made in the fields of machine learning and AI will open the door to a multitude of innovative applications in ATM. Tasks will be performed collaboratively by hybrid human-machine teams, in which advanced adaptable and adaptive automation principles could dynamically guide the allocation of tasks. The goal is not automation per se but optimising the overall performance of the socio-technical ATM system and maximising human performance and engagement at all times. The synchronisation of the air and ground automation systems will make it possible to reduce both controller and flight crew

[23] The Digital Economy and Society Index (DESI) (https://ec.europa.eu/digital-single-market/en/desi)

[24] Society of Automotive Engineers Standard J3016, 'Levels of automated driving'.

FIGURE 4. LEVELS OF AUTOMATION



workload when managing or operating in busy airspace, thus supporting reduced crew operations and RPAS.

Safety science will evolve to cope with the safety challenges posed by the introduction of machine learning, developing new methodologies for the validation and certification of advanced automation that will ensure their transparency, robustness and stability under all conditions. Automation will also offer safety opportunities, making it possible to progress towards the zero-accident performance ambition in spite of traffic growth.

U-space, the development of which started in phase B, was conceived from the start without the requirement for a human to be always in the loop, and developments will continue in this direction in phases C and D. The objective is to create the building blocks of a system that provides services that are scalable for large numbers of small drones, creating an ecosystem that is very different from ATM but seamlessly integrated with it.

In phases A to C, ATC and ATFM automation developments will focus on increasing the level of system support, while the initiation of actions will always lie with the human. The breakthrough will happen in phase D, when higher automation levels will remove the human from the loop for selected ATC tasks. Human cognitive limitations will no longer limit the capacity of the airspace by design.

Automation in phase D will also enable advanced collaboration paradigms between different human and machine ATM agents. ATC will orchestrate the overall traffic density in collaboration with ATFM, while pilots and on-board automation systems may be allocated specific tasks by delegation. The boundaries between ATC and ATFM will progressively blur, as automation takes on more and more of the tactical ATC tasks and makes it possible to implement more flexible ATFM concepts that rely on advanced tactical support.

2.3 DELIVERING A DIGITAL EUROPEAN SKY IN FOUR PHASES

The digital European sky is an evolution of the European airspace architecture that leverages modern digital technologies to decouple service provision from local infrastructure. At the same time, it progressively increases the levels of collaboration and automation support through a data-rich and cyber-secure connected digital ecosystem. This evolution will open up new business opportunities through the creation of a dynamically distributed system, while fully respecting the sovereignty of Member States in relation to their airspace. Airspace configuration and design will be optimised from a European network point of view, connecting airports and taking into due consideration major traffic flows across Europe. Data services made available to trusted users will feed advanced ATC tools, allowing operational harmonisation, bringing the level of performance to new heights and eventually realising the virtual defragmentation of European skies.

The system will serve a growing number of increasingly diverse aircraft (manned and unmanned), with more aircraft than ever before in the air at any moment in time. With the full deployment of U-space, drones (civil and military) will be completely and seamlessly integrated into all environments and classes of airspace, operating safely and efficiently alongside manned aircraft. Trajectory-based free-route operations with performance-based navigation (PBN) take place in airspace configurations designed to optimise the performance of operations while providing a high level of service and meeting ambitious EU standards for safety and security.

The system infrastructure will progressively evolve with the adoption of digital technology, allowing civil and military ANSPs and the Network Manager to provide their services in a cost-efficient and effective way irrespective of national borders, supported by a range of secure information services. Airports and other operational sites (e.g. for rotorcraft and drones) will be fully integrated into ATM at network level, which will facilitate and optimise airspace user operations.

The achievement of the digital European sky and maximising performance gains will require a change in the approach to how SESAR Solutions are developed and deployed and how services are provided. Through four transitional phases, the system architecture will gradually move away from a country-specific architecture to a more interoperable, global and flexible service provision infrastructure. It should be noted that these transitional phases will overlap and that the first three phases are already being deployed or in the pipeline towards deployment.

PHASE A. Address known critical network performance deficiencies

Although most ANSPs are vertically integrated into country-based infrastructures, this phase sees the initial adoption of a service-oriented architecture as an enabler for TBO. The sharing of data and information is enabled by SWIM implementation and the introduction of open architectures and standards, as well as common data layers. Specific measures related to the protection of ATM systems and infrastructures against cyberattacks are jointly implemented to ensure the continuity and the integrity of the operations.

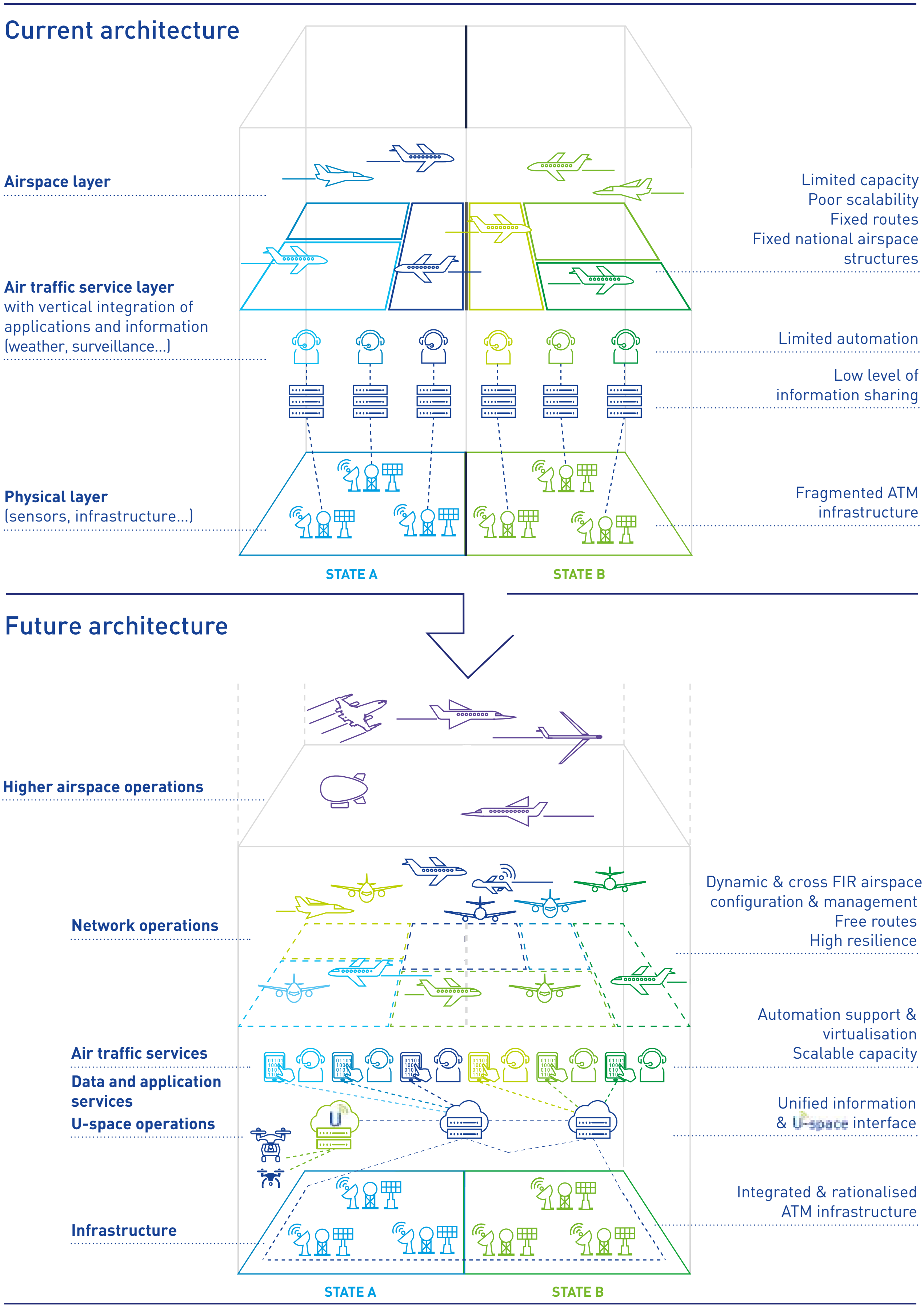
This approach allows increased information sharing across national borders and exchange between ATM stakeholders, including the Network Manager, airlines, airports and the military. In this way, it targets both ground-ground and air-ground communications with the implementation of the SWIM blue profile (flight object interoperability), the automatic dependent surveillance contract/extended projected profile (ADS-C/EPP) and controller-pilot datalink communications.

This phase has already started, with the deployment of solutions delivered by SESAR and mainly, but not exclusively, deployed through the PCP.

PHASE B. Efficient services and infrastructure delivery

The development of open standards for ATM systems also means that stakeholders will find commonalities in terms of their operations and service needs, allowing for the development and introduction of a common service layer achievable through a set of ADSPs. This will make possible the optimisation and rationalisation of ATM support services, enabling a move

FIGURE 5. **EVOLUTION OF THE EUROPEAN SKY**



from physical infrastructures to virtual infrastructures that are characterised by automation and increased sharing of data and information to enhance predictability and enable the remote provision of ATS. This phase is reliant on the delivery of a continuous flow of solutions from the SESAR 2020 R&D activities and demonstratable evidence of the related performance gains expected from Europe-wide and/or local deployment, where appropriate. In tandem with the more efficient organisation of infrastructure and services, this phase will see the business cycles of the traditional ATM stakeholders gradually start to shorten and move towards the accelerated cycles already seen with the integration of new entrants (e.g. drone operators, very high-altitude operators, mobility providers, U-space service providers) into the aviation environment.

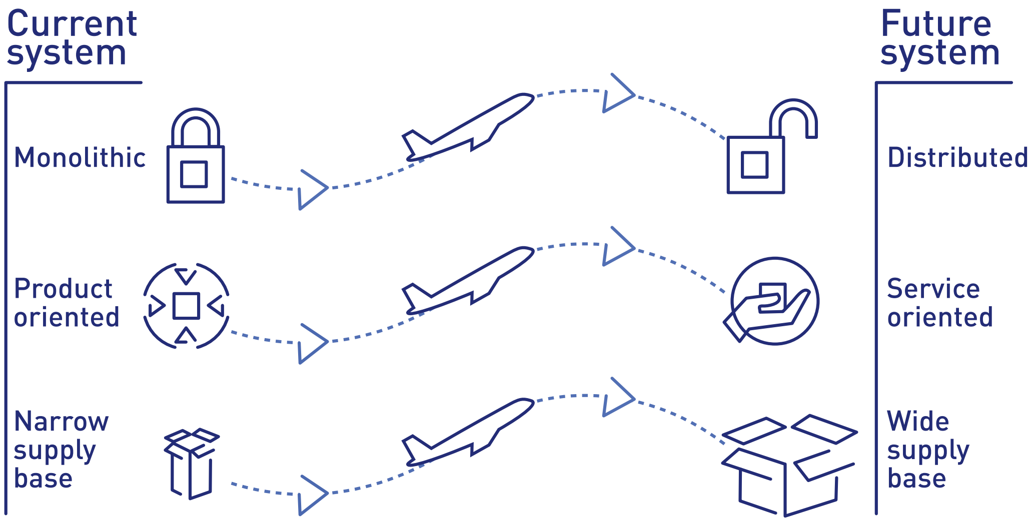
PHASE C. Defragmentation of European skies through virtualisation

By this phase, the ATM system will have gradually integrated greater levels of automation and connectivity, supporting higher productivity and full sharing of information among stakeholders. It will be using standardised and interoperable systems enabling TBO in a highly connected, service-oriented, network-driven context. The collaborative planning and decision process will allow each flight to be managed and optimised as a whole rather than in relation to segmented portions of its trajectory. This phase will also see the full integration of airports into the ATM network, facilitating airspace user operations and thereby reducing the impact of ATM on user costs. This will be possible thanks to the involvement of airspace user / flight operations centres, dynamic demand - and capacity-balancing (DCB) management, and further integration of ATC and ATFCM. The data provided through ADSPs and a more flexible system with improved and new services, such as capacity on demand, will fully support the implementation of these operations. This integration will certainly be gradual; it may start at a regional level or for some alliances of ANSPs.

The new architecture will make it possible to decouple the system infrastructure from ATC operations. ANSPs, irrespective of national borders, will be able to plug in their services where they are needed, providing end-to-end services and sharing resources among ANSPs.

In this phase, drone operations (UAS and RPAS) could be managed as routine operations even if not yet fully integrated into ATM. Additional services, along with new ground and air capabilities, will

FIGURE 6. **TOWARDS A DIGITAL ECOSYSTEM**



make it possible to manage safely a large number of diverse drone operations in all environments, including urban areas, for which specific requirements will be set up.

This phase is also reliant on the delivery of solutions arising from the SESAR 2020 R&D activities and demonstrable evidence of the performance gains expected from Europe-wide, regional and/or local deployment, where appropriate.

PHASE D.
Target vision: the digital European sky

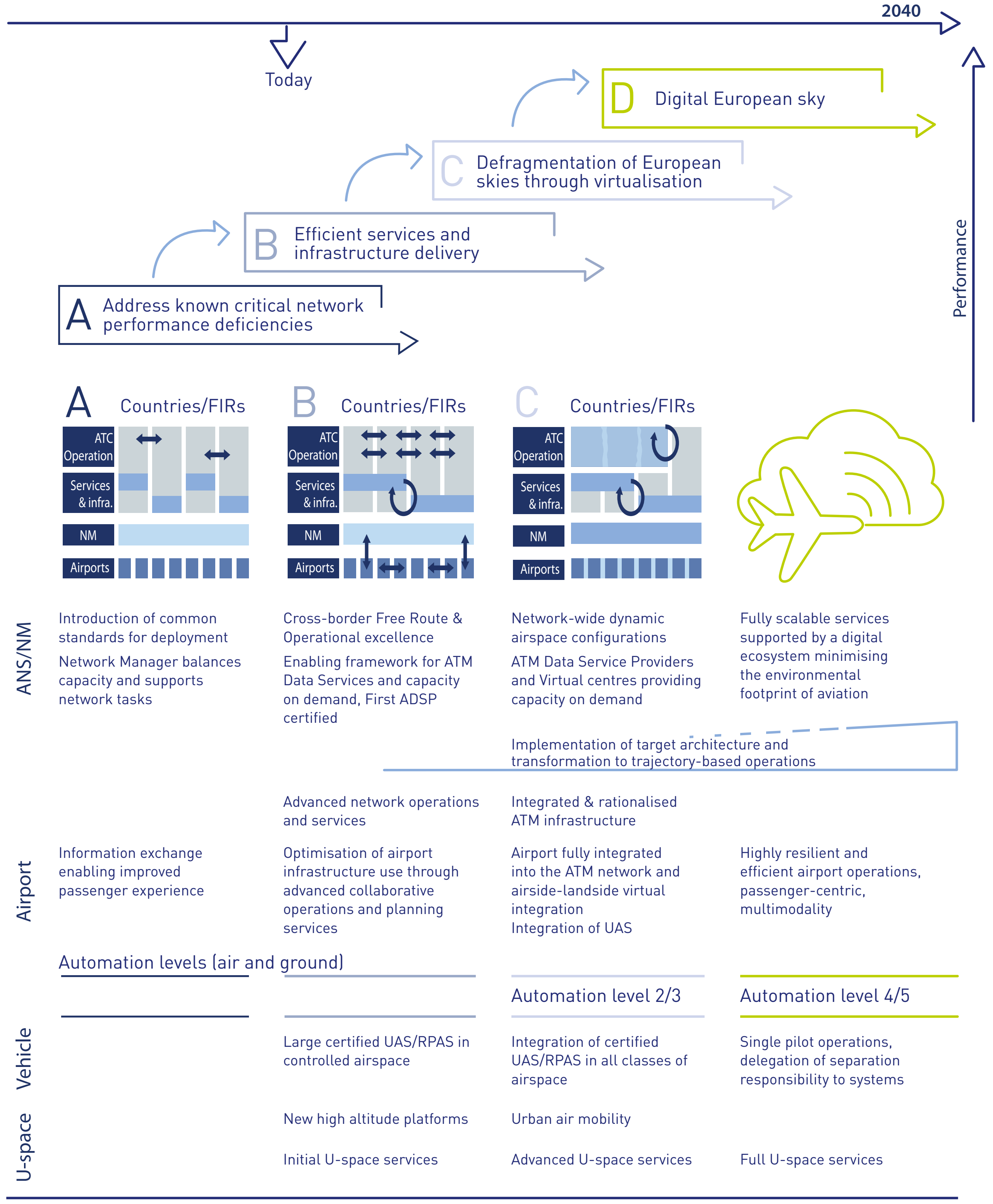
ATM and aviation will evolve into an integrated digital ecosystem characterised by distributed data services. Phase D aims to deliver a fully scalable system for manned and unmanned aviation that is even safer than today's, based on high air-ground integration and leveraging digital technologies to transform the sector.

By the time this phase is activated, the core ATM system will have reached a high degree of automation in the air and on the ground. Phase D will advance the level of automation at least to Level 4 (as depicted in **FIGURE 4**). Airborne operations will comprise a considerable mix of flight profiles and airborne capabilities, giving rise to a high level of complexity. AI will offer significant support to pilots and controllers, substantially alleviating the workload generated under these conditions. Pilots are likely to count on digital assistants powered by AI to automatically negotiate with the ground and manage any trajectory changes. On the ground, in a joint cognitive system, ATCOs could delegate a large portion of their tasks to machines that can help in a safe and efficient manner. The system will propose the best possible options to the human (flows, sequences, safety net, etc.) and will solve complex trajectory situations using machine-to-machine communication with air vehicles.

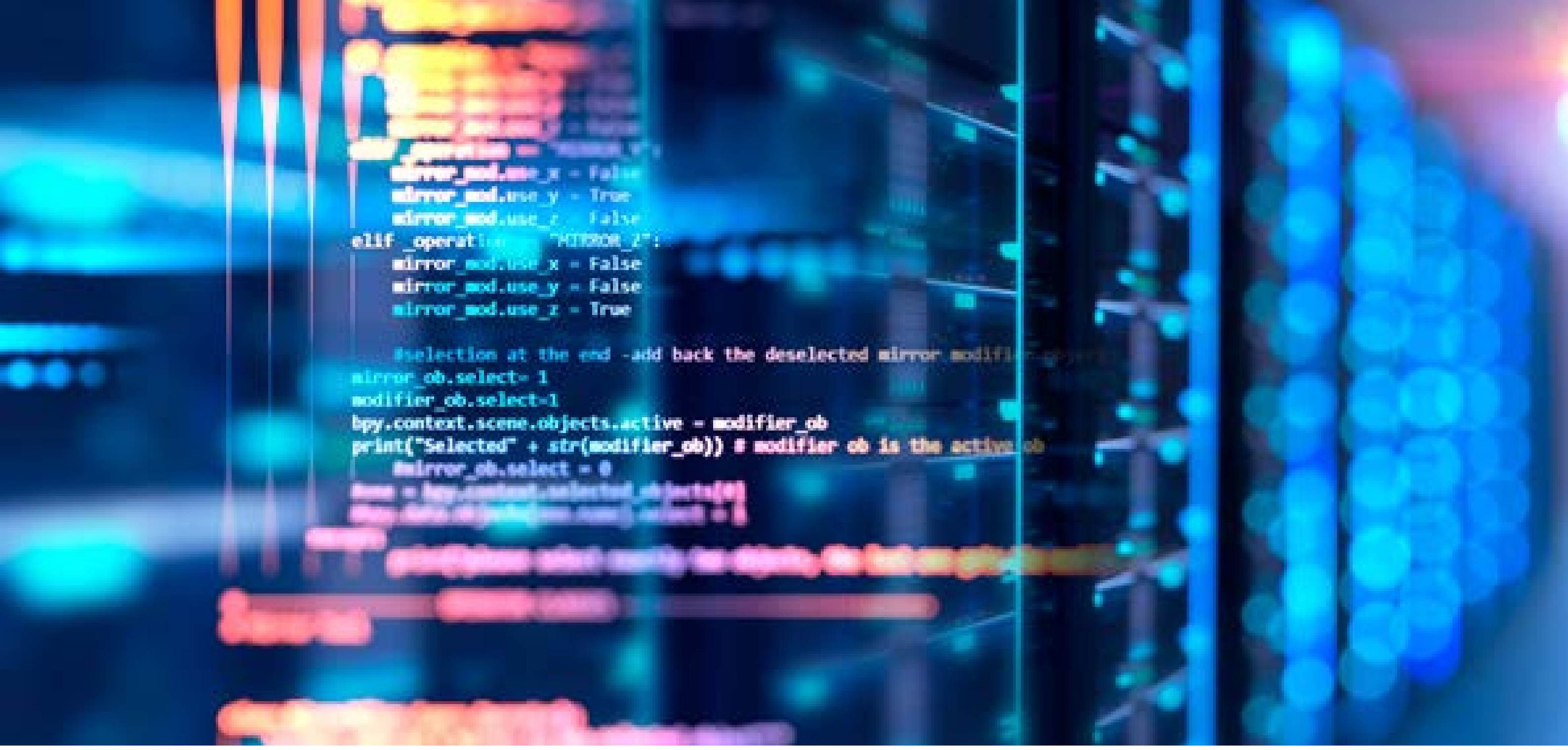
Well in advance, using advanced analytics, the network will be capable of building a very accurate picture of the predicted traffic situation. In order to solve capacity bottlenecks, in coordination with the stakeholders involved, the airspace will be dynamically reconfigured and sufficient capacity could be created by activating capacity on demand services. As a result, all demands would be accommodated with no or very small delays.

Smart airports will become a reality, with airports placing connectivity and other technologies at the centre of their business to redefine the user experience while improving operations. Advanced virtual technologies will enable all-weather operations and reduce delays.

FIGURE 7. **FOUR-PHASE APPROACH TO IMPROVEMENTS**



The full implementation of concepts such as infrastructure as a service (IaaS), platform as a service (PaaS) and software as a service (SaaS) will enable the complete decoupling of service provision (infrastructure services, information services and all other ANS) from the physical location of the infrastructure. This will rely on hyper-connectivity between all stakeholders (ground-ground and air-ground) via high-bandwidth, low-latency fixed and mobile networks. Highly automated systems with numerous actors will interact with each other seamlessly,



with fewer errors. Scaling of system performance will happen in quasi-real time, as and when required. In this context, multiple options can be envisaged for the reorganisation of services in relation to geography and flight execution (e.g. seamless collaboration between ANSPs across Europe and/or end-to-end ANS provision).

Many types of civil airspace users will be part of or provide services to providers of mobility as a service. This will offer customers a seamless and hassle-free travel experience combining different modes of transport for door-to-door journeys. Autonomous vertical take-off and landing-capable air taxis will provide new ways to connect airports with populated areas. For example, urban air mobility will feature flying taxis operating at low and very low levels in urban and suburban areas, evolving from today's helicopters towards increasingly autonomous operations using alternative propulsion and new vehicle designs. Urban air mobility will be one of the most demanding use cases for U-space.

However, enabling growth for the sake of growth is not the objective. Aviation has externalities that cannot be overlooked. Indeed, as air traffic will have increased significantly year on year, the same holds true for environmental and health impacts. This is why, with the delivery of the digital European sky, SESAR will enable an irreversible shift to low- and ultimately no-emission mobility; the vision is zero inefficiencies due to traffic management by 2040. This commitment shown by aviation stakeholders confirms SESAR's long-standing efforts to ensure that European citizens can travel by air while leaving a minimal environmental footprint.

Delivery of the digital European sky by 2040 is ambitious and will require, from 2020 onwards, a new way of working within SESAR, combined with changes to the regulatory framework to further shorten innovation cycles and time to market. It is only by introducing these bold changes in a timely manner that the aviation infrastructure will be able to effectively and sustainably cope with the entry into service of new types of vehicles expected to shape the future of aviation.

PERFORMANCE VIEW

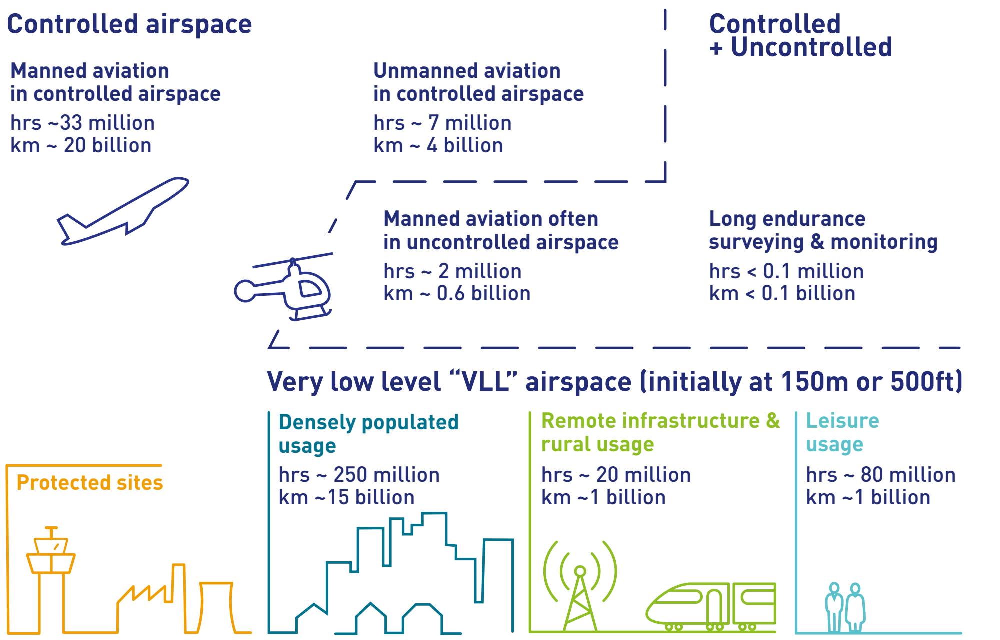
This chapter outlines SESAR's performance ambitions. Section 3.1 sets out the overarching ambition while Section 3.2 confirms and details performance ambitions described in the previous edition of the Master Plan in relation to manned aviation (controlled airspace) up to Phase C of the vision.

3.1 DELIVERING A FULLY SCALABLE SYSTEM THAT IS EVEN SAFER THAN TODAY'S

Major developments will require a profound transformation of ATM technology to support safe operations in both controlled and uncontrolled airspace; growth in the volume and diversity of air traffic; moves towards automation in the ATM sector; parallel moves towards automation in other transport sectors; and increasing reliance on digitally shared information.

- **Growth in the volume and diversity of air traffic.** By 2050, air traffic will consist of tens of millions of annual flights. As shown in **FIGURE 8**, the vast majority of this traffic will originate from new types of vehicles (e.g. drones) operating in airspace previously not used: VLL airspace (initially below 150 m or 500 ft) away from aerodromes. In the airspace at and above 500 ft, which includes both controlled and uncontrolled airspace, manned traffic will still exceed unmanned aviation in 2050, but this airspace will be profoundly different from today due to the increased density and diversity of traffic. Also here, the interactions between the various types of traffic will not necessarily be driven entirely by humans (e.g. SPO leading to an increased degree of airborne automation, unmanned cargo requiring fully automated ATM interactions). The entry into service of the most significant of these new types of aircraft is expected to gradually scale up from 2030, which is when the supporting infrastructure needs to be ready to accommodate this new air traffic. Demand for access to lower level airspace is already growing rapidly as more and more drones are taking to the sky every day, for leisure but also increasingly to deliver professional services (e.g. for inspections and data collection, and for public safety and security purposes, but soon also for parcel delivery and urban air mobility). Two key implications follow. First, managing this level of air traffic at current productivity levels will be unsustainable, given the cost implications and the limited gains in efficiency that can be achieved by further splitting of sectors (airspace elasticity). Second, increased traffic levels and new forms of traffic (including military traffic such as RPAS and fifth generation fighter aircraft) with diverse communication technologies, flight and speed patterns, etc., will lead to unprecedented levels of heterogeneity and complexity in vehicles, requiring further automation, connectivity and interoperability. On both counts, the uncertainty of the timing and magnitude

FIGURE 8. **IMPACT ON AIRSPACE OF MANNED VERSUS UNMANNED OPERATIONS, MEASURED IN FLIGHT HOURS AND DISTANCES EXPECTED BY 2050**



Source: SJU, European drones outlook study, 2016 (https://www.sesarju.eu/sites/default/files/documents/reports/European_Drones_Outlook_Study_2016.pdf)

of the change requires the future ATM system to be fully scalable to ensure a cost-efficient ATM system with safety above current levels.

- **Growing environmental challenge in the years to come.** While the benefits of continued growth in air traffic for EU citizens are clear in terms of mobility, connectivity and availability of new services (e.g. those enabled by drones), this growth represents a significant environmental challenge in the years to come. Concerns in this regard in Europe and worldwide are prompting the aviation industry to step up its efforts to address the environmental sustainability of air travel and reach the EU's carbon neutral goal by 2050. In support of this goal, the SESAR project will gradually contribute to the elimination of environmental inefficiencies caused by the underlying aviation infrastructure, by ensuring that it offers solutions that will fully exploit the potential offered by next generation aircraft for cleaner and quieter flight.

- **Moves towards automation in other sectors will also shape the future of flight.** The convenience of using a technology or a service increases with the number of users that adopt it. Public acceptance of change in the aviation technology landscape at large will therefore increasingly be influenced by moves towards automation in other safety-and security-critical sectors (e.g. automotive industry, energy and banking). Such acceptance has already been observed in the rapidly expanding leisure or semi-professional drone sector.

- **Increasing reliance on digitally shared information.** Advances in technology will make it possible for companies to collect, store and use large amounts of data to deliver new, innovative services the relevance of which for flight safety will continue to increase. This increased reliance on digitally shared information will increase the need for strong cybersecurity systems.

Primarily driven by growth in the volume and diversity of air traffic, these additional changes require the ATM sector to set the performance ambition of delivering a fully scalable system that is even safer than today's, while contributing to the elimination of environmental inefficiencies due to the underlying aviation infrastructure.

3.2 CONFIRMING THE 2035 PERFORMANCE AMBITIONS FOR CONTROLLED AIRSPACE AND AIRPORTS

This section outlines the performance ambitions linked to the timely implementation of SESAR phases A to C, excluding U-space, aligned with the implementation of the vision (see Chapter 2). The performance ambitions are outlined in relation to several key performance areas (KPAs) including those set by SES (see Chapter 1) and defined in the SES performance scheme [25].

As the technological pillar of SES, SESAR is a key contributor to the SES high-level goals, through the delivery and deployment of SESAR Solutions with demonstrable and measurable performance benefits. As the SESAR project must take into account lengthy investment lead times, which are common in infrastructure industries such as ATM, and therefore the need to stimulate sustained R&D activities for the future, the performance ambitions are not binding, in contrast with the performance targets established in the performance scheme for the performance reference periods. Longer look-ahead times bring increased uncertainty with regard to the level of performance. In particular, regardless of the steady growth foreseen in the medium to long term, there is a perceptible degree of uncertainty about how volumes of traffic will change, which is taken into account in the SES legislative package through the risk-sharing mechanism. Therefore, contributions to 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 to ensure that they reach their full potential.

In this context, the SESAR project is expected to contribute to achieving the targets established in the SES performance scheme. Nevertheless, its contribution to the various KPAs described in this section will need to be validated on the basis of the research outcomes for each SESAR Solution and reviewed in the context of deployment activities, which may depend on local circumstances and the availability of sufficient deployment capacity to bring the changes into operation.

The performance ambitions set out in this section are based on the assumption that SESAR Solutions covering phases A to C (and excluding U-space) are being made available through R&D activities deployed in a timely manner and used to their full potential. These ambitions provide a common reference point for the ATM stakeholder community, which it can use to determine development and deployment priorities. Unless otherwise specified, the specific values given for the performance ambitions refer to the European Civil Aviation Conference (ECAC) area as a

[25] European Commission, Commission Implementing Regulation (EU) 2019/317 of 11 February 2019 laying down a performance and charging scheme in the single European sky and repealing Implementing Regulations (EU) No 390/2013 and (EU) No 391/2013, OJ L 56, 5.2.2019, p. 1-67.

whole [26] and are linked to the 2035 target date. Performance ambitions were first introduced in 2012, which was also the start of the SES performance scheme's first period. The aim is to ensure continuity between Master Plan editions.

The performance ambitions are categorised according to the SES KPAs: capacity, safety, environment and cost efficiency. Two additional KPAs, namely operational efficiency and security, have been identified as important contributors to SESAR performance and have been included.

For this edition of the Master Plan, the 2035 ambitions have been confirmed using a data-driven approach, which links current and forecast data to target agreed performance improvements, challenging but realistic, for various lower-level performance indicators, typically at the level of individual flight phases. These have been combined with anticipated 2035 traffic levels [27] to link to the ambitions shown in **FIGURE 10**. The ambitions and all other performance parameters use 2012 performance levels as a baseline.

Achieving the performance ambitions for 2035 is subject to optimal development and deployment of the most relevant, mature and best-performing SESAR Solutions. The resulting changes and the related R&D activities are detailed in Chapter 4, while the benefits are evaluated in Chapter 6.

The combination of sustained air traffic growth forecasts and the emerging capacity constraints substantiate the need to maintain and even reinforce the performance ambitions set for 2035 in the 2015 edition of the Master Plan. This is also supported by evidence of performance gains from the solutions deployed so far.

- **Air traffic growth.** Air traffic growth has increased in recent years, reaching more than 11 million ECAC instrument flight rules (IFR) flights in 2018 (i.e. 13.4 % more flights than in 2012). Furthermore, observations confirm that new trends, since 2015, are driving air traffic growth, making a high-growth scenario more likely in the long term. These trends include the expansion or building of airports (e.g. Istanbul), a rise in low-cost long-haul flights (e.g. Norwegian) and the emergence of the Asian middle class, leading to increased demand for air travel. In accordance with the regulation and growth forecast by EUROCONTROL's statistics and forecasts service (STATFOR), the traffic forecast for 2035 has been revised upwards from 14.4 million to 15.2 million flights.

- **Growing capacity constraints.** The upwards trend in air traffic indicates that capacity constraints have become a key challenge, and the situation is expected to deteriorate further in the coming years if changes supported by systems are not introduced to the current airspace architecture, airport capacity and ATM operations. The SES delay target (0.5 min/flight) established in the performance scheme has not been met since 2015, mainly because of ATC capacity and staffing constraints, as shown in **FIGURE 9** [28].

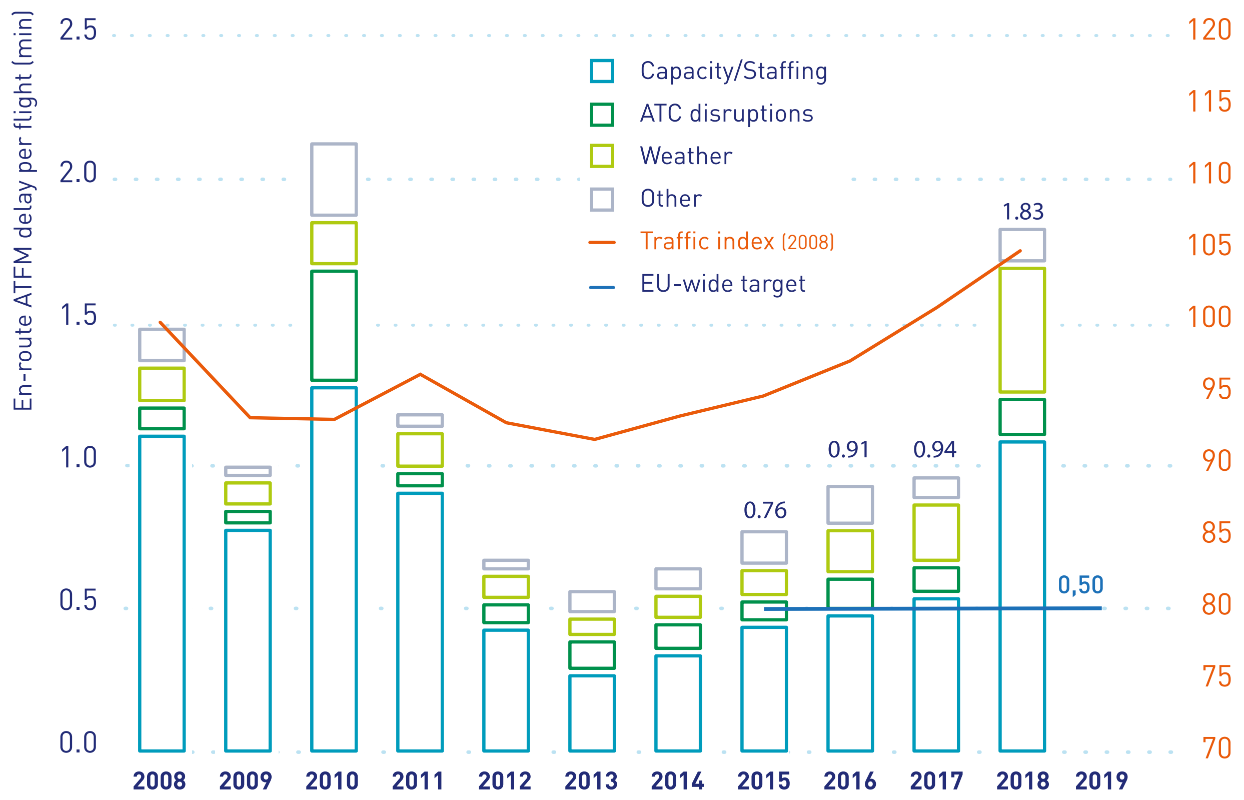
  In 2017, there was an average 0.94 minute en-route ATFM delay per flight, while in 2018 the average en-route delay was 1.83 minutes per flight. Performance is expected to deteriorate further in the coming years if stringent actions are not taken. The capacity crunch is also affecting airports: in the absence of bold action, according to the current Eurocontrol Challenges of Growth-study the persisting capacity crunch may lead to 1.5 million unaccommodated flights in

[26] Geographical scope as defined by EUROCONTROL's statistics and forecasts service (Statfor), including the North Atlantic oceanic airspace managed by the European ANSPs.

[27] EUROCONTROL, STATFOR 'Challenges of Growth', 2018 (https://www.eurocontrol.int/publications/flight-forecast-2040-challenges-growth-annex-1). Note that for the 2035 traffic level the regulation and growth scenario was used. This scenario is deemed to be the most robust one. It incorporates not only the increase in the number of flights but also other aspects of traffic evolution that are part of the forecast, such as a progressive increase in average flight distance and duration, a continued trend towards larger aircraft, the prediction that intercontinental traffic will grow faster than internal ECAC traffic, etc. This data-driven approach ensures that a fully consistent set of performance parameter values for 2035 is readily available, as well is a breakdown of the ambitions into more specific performance improvements, including in relation to the indicators used in the SES performance scheme.

[28] Values shown are for SES reference period 2 (2015-2019).

FIGURE 9. **AVERAGE EN-ROUTE DELAY 2008-2019**



Source: EUROCONTROL, Performance Review Unit

FIGURE 10. **PERFORMANCE AMBITIONS FOR 2035 FOR CONTROLLED AIRSPACE**

Key performance area	SES high-level goals 2005	Key performance indicator	Performance ambition vs. baseline: Baseline value (2012)	Ambition value (2035)	Absolute improvement	Relative improvement
Capacity	Enable 3-fold increase in ATM capacity	**Departure delay**[4],min/dep	9.5 min	6.5-8.5 min	1-3 min	10-30%
		IFR movements at most congested airports[5], million	4 million	4.2-4.4 million	0.2-0.4 million	5-10%
		Network throughput IFR flights[5], million	9.7 million	~15.7 million	~6.0 million	~60%
		Network throughput IFR flight hours[5], million	15.2 million	~26.7 million	~11.5 million	~75%
Cost efficiency	Reduced ATM services unit costs by 50% or more	**Gate-to-gate direct ANS cost per flight**[1] · EUR(2012)	EUR 960	EUR 580-670	EUR 290-380	30-40%
Operational efficiency		**Gate-to-gate fuel burn per flight**[2], kg/flight	5280 kg	4780-5030 kg	250-500 kg	5-10%
		Additional gate-to-gate flight time per flight, min/flight	8.2 min	3.7-4.1 min	4.1-4.5 min	50-55%
		Within the: Gate-to-gate flight time per flight[3], min/flight	(111 min)	(116 min)		
Environment	Enable 10% reduction in the effects flights have on the environment	**Gate-to-gate CO_2 emissions**, tonnes/flight	16.6 tonnes	15-15.8 tonnes	0.8-1.6 tonnes	5-10%
Safety	Improve safety by factor 10	**Accidents with direct ATM contribution**[6], #/year Includes in-flight accidents as well as accidents during surface movement (during taxi and on the runway)	0.7 (long-term average)	no ATM related accidents	0.7	100%
Security		**ATM related security incidents resulting in traffic disruptions**	unknown	no significant disruption due to cyber-security vulnerabilities	unknown	-

1 Unit rate savings will be larger because the average number of Service Units per flight continues to increase.
2 "Additional" means the average flight time extension caused by ATM inefficiencies.
3 Average flight time increases because the number of long-distance flights is forecast to grow faster than the number of short-distance flights.
4 All primary and secondary (reactionary) delay, including ATM and non-ATM causes.
5 Includes all non-segregated unmanned traffic flying IFR, but not the drone traffic flying in airspace below 500 feet or the new entrants flying above FL 600
6 In accordance with the PRR definition: where at least one ATM event or item was judged to be DIRECTLY in the causal chain of events leading to the accident. Without that ATM event, it is considered that the accident would not have happened.

2040, an equivalent to circa 160 million passengers unable to fly.

Furthermore, capacity growth has become increasingly complex and more costly, both from an ATM perspective and from an airport perspective; growing airport capacity involves long lead times, is complex to implement because of the consultation and planning required, and is therefore now a priority. Last but not least, sector configurations are driven by national borders rather than traffic flows, resulting in significant variations in ATCO workload across sectors and complex capacity management.

- **Evidence of the positive impact of the solutions deployed.** The progress in the development and deployment of SESAR Solutions confirms the SESAR's potential to address current and future challenges and improve the performance of the system.

Meeting the ambitions is conditional on two (non-exhaustive) key requirements being met. First, the regulatory/institutional landscape and the business models of actors in the value chain need to evolve to enable a significant part of SESAR's expected impact. Second, automation at higher levels than outlined in the previous edition of the Master Plan will be a key enabler of meeting the performance ambitions.

The following subsections detail the 2035 performance ambitions for controlled airspace at KPA and key performance indicator (KPI) levels.

In this edition, In comparison with performance ambitions defined in the Master Plan 2015 edition, some refinements have been made in this edition. The cost efficiency, fuel efficiency and environment ambitions have been maintained. However, the average take-off weight and average flight time of IFR flights in 2035 will be significantly greater than in 2012, leading to an increase in fuel burn per flight. This effect is clearly noticeable in the period 2012-2018 ([29]).

It is therefore important to be aware of the challenges involved in meeting this performance ambition, and, as already noted, contributions from beyond SESAR are needed. Further details for each KPA are given in the subsections below. Performance improvements delivered by the programme are to be judged as benefits against a do-nothing scenario, which is the basis for the business view in Chapter 6.

For some KPAs, the refinement of the ambitions has resulted in the 2015 capacity ambition being maintained, resulting in an increased need for capacity owing to the higher traffic forecasts. The measures proposed in the Airspace Architecture Study are expected to substantially help in achieving this ambition in a context that is even more challenging than in 2015. The safety ambition has also increased, and is now expressed as zero accidents with direct ATM contribution (which includes in-flight as well as surface movement accidents). Finally, there has been a small increase in the ambition level for departure delay reduction.

Overall, these refinements confirm the performance ambitions for 2035 expressed in the 2015 edition of the Master Plan.

3.2.1 Capacity

3.2.1.1 Introduction

Statfor's *Challenges of growth* report foresees 1.5 million unaccommodated flights by 2040, resulting in 470 000 passengers per day being delayed by 1-2 hours, compared with 50 000 passengers in 2018 ([30]).

Mindful of this forecast, the ambition is to tackle this capacity crunch, address the risk of unaccommodated traffic and increase the network traffic throughput in order to accommodate predicted demand with a sufficient margin. It also intends to provide sufficient scalability at key bottlenecks in the network to

([29]) Eurocontrol, 'Flight forecast to 2040 — challenges of growth', 2018 (https://www.eurocontrol.int/publications/flight-forecast-2040-challenges-growth-annex-1).

([30]) In the 'Regulation and Growth' scenario envisaged by STATFOR. See Eurocontrol, 'Flight forecast to 2040 — challenges of growth', 2018 (https://www.eurocontrol.int/publications/flight-forecast-2040-challenges-growth-annex-1).

enable reductions in ATFCM delays and increase the potential for fuel-efficient trajectories.

The capacity ambition is to accommodate all traffic forecasts in the 'Regulation and Growth' scenario, including the additional 'recovered' unaccommodated demand, which can be realised through SESAR-enabled capacity improvements at the most congested airports.

The capacity performance ambitions KPAs shown in **FIGURE 10** include departure delay. Because the scope of the ambition extends beyond capacity, departure delay is discussed in the context of operational efficiency, in Subsection 3.2.3.

3.2.1.2 Capacity ambitions in relation to congested airports

In 2035, bottlenecks are expected to develop in locations where there is insufficient terminal airspace and airport capacity. The *Challenges of Growth* report foresees approximately 0.9 million flights unaccommodated in 2035. The issue is not so much a lack of overall capacity rather than a lack of capacity in certain locations or at certain periods of time which could be exacerbated by a lack of potential for growth (e.g. for the construction of additional runways and terminal infrastructures).

This potential lack of airport capacity will have a knock-on effect on other operating environments, which will also need to be managed. Exhaustive use of saturated airports will adversely impact predictability and punctuality, making meeting performance ambitions all the more challenging.

The ambition is to enable a 5-10 % capacity improvement in highly congested airports (which altogether handled 4 million movements in 2012). This will allow an additional 0.2 million-0.4 million movements on top of the forecast Statfor value. In addition, the overall traffic growth will encourage regional and local airports to develop, supporting an increase in direct flights between European regional cities.

Meeting these performance ambitions will also require means of increasing capacity — such as the construction of additional runways and terminal infrastructures — at airports that are not covered by or within the scope of SESAR. However, this is a subject for local decision-making parties to consider, and will involve extensive consultation periods for planning consent and airspace changes.

3.2.1.3 Airspace and network capacity ambitions

At ECAC level, the network will need to accommodate an increase of up to 15.7 million flights, which is an increase of about 60 % compared with 2012. These flights correspond to 27 million IFR airport movements network-wide, representing growth of 56 %.

Airspace capacity needs are better expressed in terms of IFR flight hours. Owing to a slow but steady increase in average flight distance, there is a need for the ATM system to control 26.7 million IFR flight hours in 2035, which is an increase of 75 % compared with 2012. In terms of the distance flown, the increase is 80 %. Sufficient capacity margins must be provided to enable the achievement of the ambitions in the other KPAs.

The capacity performance ambitions are not all expressed as ranges, because they are taken from the traffic forecasts in the 'Regulation and Growth' scenario envisaged in the 2018 *Challenges of growth report.*

3.2.2 Cost efficiency

SESAR delivers a portfolio of solutions capable of enhancing ANS productivity. The ambition is to provide necessary technical system changes, at reduced life cycle costs, while continuing to develop operational concepts to enhance the overall productivity of ANS provision.

In 2012, the gate-to-gate direct ANS cost for the ECAC area was approximately EUR 9.28 billion for 9.71 million flights, which corresponds to a unit cost of EUR 960 per flight ([31]).

By 2035, the performance ambition for the ECAC area is to allow a reduction of 30-40 % (equivalent to EUR 290-380 per flight ([32]) in the cost per flight compared with 2012. The ANS cost performance ambition is to achieve a gate-to-gate direct ANS cost of EUR 670-580 per flight. With traffic volume projected to reach 15.7 million flights, this will entail keeping the annual gate-to-gate direct

([31]) ATM cost effectiveness 2012 benchmarking report data for 37 ANSPs, enhanced with data on a further two ANSPs to achieve almost total ECAC coverage (Azerbaijan missing), https://www.eurocontrol.int/ACE/ACE-Reports/ACE2012.pdf.

([32]) Unless otherwise specified, all financial values are expressed in euros as in 2012 (in real terms; that is, adjusted for inflation).

ANS cost of the ECAC area as a whole at constant levels in the face of significant traffic growth. The achievement of these cost efficiency improvements will involve initiatives addressing both ANS productivity and significant organisational changes, as indicated in the SESAR vision (see Chapter 2). In this way, cost efficiency ambitions will be fulfilled while still allowing delivering the capacity needed.

The extent to which these gains can be realised will depend on how the SESAR Solutions are deployed, developments with regard to traffic growth and the validation of the SESAR Solutions' performance potential. It should be noted that this cost efficiency ambition does not take into account the cost of change or the possible restructuring costs incurred.

3.2.3 Operational efficiency

In addition to direct gains in terms of cost efficiency, SESAR will also bring indirect economic benefits for flight operations, mainly through the reduction and better management of departure delays and more efficient flight paths, reducing both the additional fuel consumption attributable to ATM and gate-to-gate flight time, and increasing predictability. It will also significantly reduce the need for intervention by operators (ATCOs, airline ground operators, flight crew, etc.), which is assessed in other KPAs. For the military, operational efficiency is an enabler of mission effectiveness. This means the best possible adherence between the planning and the execution phase of the mission (e.g. in relation to fine-tuning of the transit time from/to the home base, real occupancy of the reserved airspace).

3.2.3.1 Fuel efficiency

The fuel efficiency performance ambition addresses the average gate-to-gate fuel consumption per flight. This includes efficiency on the airport surface as well as flight trajectory efficiency (including horizontal, vertical and time efficiency). The aim of ATM improvements is to achieve a significant reduction in the fuel inefficiency induced by ATM-related trajectory constraints while maintaining the ability to accommodate traffic increases safely and ensuring the achievement of the punctuality objectives of airspace users.

The high-level ambition is to achieve a reduction in total gate-to-gate fuel burn of 250-500 kg from a baseline of 5 280 kg for an average flight in 2012. This ambition is challenging when seen in the light of historical and projected trends in fleet composition and traffic patterns, which affect fuel burn regardless of ATM performance. For example, in the past 6 years (i.e. 2012-2018) the average maximum take-off weight of aircraft flying IFR in the ECAC area has increased

from 77 to 86 tonnes (+12 %), and in addition the average distance flown has increased from 1 120 km to 1 210 km (+8 %). As a result, the average gate-to-gate fuel burn per flight has increased from 5 280 kg to 5 790 kg (+17 %); however, in terms of average fuel burn per tonne-kilometre, there was a notable improvement: a decrease from 61.1 g to 55.5 g (–9 %).

3.2.3.2 Time efficiency — shorter gate-to-gate flight times

To take into account the historical and predicted future increases in average city-pair distances, the gate-to-gate flight time performance ambition does not aim for a reduction in total flight time, as can be seen in the increase from 111 minutes to an ambition value of 116 minutes (see **FIGURE 10**). The performance ambition therefore takes the form of a reduction in the total additional flight time, which is defined as the difference between the duration of the actual gate-to-gate trajectory and the duration of a corresponding unimpeded gate-to-gate trajectory.

The performance ambition is to achieve a reduction in additional gate-to-gate flight time of 50-55 %, from an ECAC-wide average value of 8.2 minutes for an average flight in 2012. The data-driven approach results in a reduction to 3.7 minutes. These savings are expected to be achieved not only in the taxi-in, taxi-out and arrival phases but also in the en-route phase of the flight. The most significant savings are expected during the taxiing and flight arrival phases; the contribution from the en-route phase will depends to a large extent on the successful implementation of the SESAR vision.

These shorter times will contribute to fuel savings, as explained in the previous subsection.

3.2.3.3 Time efficiency — improving on-time performance

In the baseline year 2012, the departure delay per flight in the ECAC area averaged approximately 9.5 minutes (primary and reactionary delays of all causes) ([33]). Of this total, approximately 40 % (or up to 3.7 minutes) is due to (directly or indirectly influenced by) ATM- and weather-related factors. The remaining time delay can be attributed to other factors, such as airline operational or technical issues, industrial action and airport security.

The performance ambition is to reduce this delay of 9.5 minutes per flight to 8.5-6.5 minutes, which is a reduction of 1 to 3 minutes or 10-30 % compared with

([33]) Central Office for Delay Analysis, a part of the Network Manager.

the 2012 baseline (note that in 2018 the delay had increased to 14.7 minutes per flight). The data-driven approach assumes a reduction to 7.0 minutes, which is expected to come from reactionary delays (–2.26 minutes), airport ATFM delays (–0.16 minutes) and ATFM weather delays (–0.04 minutes). The current trend, shown in **FIGURE 9**, with regard to en-route ATFM delays, which is a proxy for other delays, implies that the challenge of meeting this performance ambition is now even greater, owing to the recent increase in delays compared with the 2012 baseline; nevertheless, the ambition can be achieved. To reduce reactionary delay, it is essential to improve the level of predictability, which is addressed in the next subsection.

3.2.3.4 Increased predictability

In addition to reducing departure delays, the aim is to increase the predictability of flight arrivals in accordance with commonly agreed reference business trajectories, prior to push-back. Greater predictability is expected to be a key outcome of the deployment of the SESAR target concept, which anticipates a move to TBO, a highly advanced network operations planning process and extensive information exchange (see Section 4.1).

Specifically, more predictable arrivals are expected, resulting from enhanced capabilities for managing constraint factors; the key being sharing airport operating plans between airports and the Network Manager.

This in turn will have a beneficial effect in reducing the 'buffer time' that airlines factor-in to their schedules to add robustness to tactical time variations. The key phases of flight for increasing predictability are taxi-out and terminal airspace arrival.

3.2.4 Environment

The reduction in gate-to-gate CO_2 emissions is directly proportional to the average reduction in fuel burn per flight, and thus captured by the efficiency KPI. The performance ambition for the reduction in average CO_2 emissions per flight is 0.8-1.6 tonnes.

In addition to its global impact due to CO_2 emissions, aviation has local impacts, in terms of noise and local emissions, that are specific to each airport and affected by airspace constraints, the traffic mix, local land use and local geography. Therefore, the regulation of environmental impacts is also a local issue, which creates constraints that can limit traffic growth at airports. It is therefore important that greater emphasis is placed on innovative solutions to enable airports, ANSPs and airspace users to optimise trajectories while taking account of potential trade-offs between noise and

emissions. Innovation in aircraft and engine design will also be a significant contributor to better management of the trade-off between noise and emissions. SESAR Solutions for airport and terminal airspace, such as continuous climb and descent operations (CCO/CDO), curved, steep and/or segmented approaches, and noise preferential routes are being considered for deployment to address noise reduction.

Evaluation tools, the development of which was initiated during the start of the SESAR project, are available for assessing SESAR Solutions and their impact on noise and on or global or local emissions [34].

3.2.5 Safety and security

3.2.5.1 Safety

Safety improvements are one of the four SES high-level goals driving the development of ATM in Europe and one of the four KPAs addressed by the SES performance scheme. Irrespective of traffic growth, and taking into account that the ATM/ANS system must ensure gate-to-gate traffic safety (in flight as well as during surface movement, that is, during taxi and on the runway), the safety ambition is zero accidents as a consequence of ATM/ANS. Meeting this ambition will require a significant reduction in risk per individual flight, going beyond the SES high-level goal of a 10fold [35] improvement in safety.

A substantial number of SESAR Solutions are specifically focused on improving safety performance, and additional benefits are expected from the implementation of the new SESAR vision. Beyond this, all SESAR Solutions, even those not specifically targeting safety gains, will remain subject to a positive safety assessment prior to being validated as fit for deployment.

Assessment of safety risks is a cornerstone of ATM strategic planning. Furthermore, as the role of ensuring the safety of aviation systems in Europe is held by EASA, safety improvements and therefore SESAR Solutions aiming to improve safety will be implemented in accordance with the European Plan for Aviation Safety. With its total system approach to aviation safety, EASA aims to ensure a common vision and alignment of objectives between the European ATM Master Plan and the European Plan for Aviation Safety. A consistent and complementary approach to ATM and to safety- and security-related matters is deemed to provide greater efficiency in achieving safety and efficiency

[34] Environmental assessments are addressed in the *European aviation environmental report, produced jointly by EASA, Eurocontrol and the European Environment Agency; the latest edition was published in January 2019,* https://www.eurocontrol.int/sites/default/files/publication/files/eaer-2019.pdf.

[35] A proxy based on the finding that safety risk increases by a cubic factor when traffic doubles.

goals, and it may prepare the ground for a unified aviation risk management framework.

3.2.5.2 Security

The overall objective is to ensure that the airspace and the ATM system, including ATC and CNS infrastructure and airports, as well as ATM-related information, are adequately protected against security threats, meeting the expectations of European citizens and policymakers.

The aim of security risk management is to support the ATM community, which requires secure, safe, efficient and rapid access to the system and information. In the event of (cyber)security threats to aviation that may disrupt operations or endanger operational safety, ATM requires sufficient protection through security controls, measures to ensure resilience, and the provision of appropriate assistance and information.

The objective in terms of cybersecurity is to ensure that adequate protection is in place to ensure that ATM systems and services, including ATM operations, are cyber-resilient. The ambition for 2035 is to have no significant network or ATM business disruption due to cybersecurity-related incidents.

Additional information on cybersecurity can be found in Section 4.6.

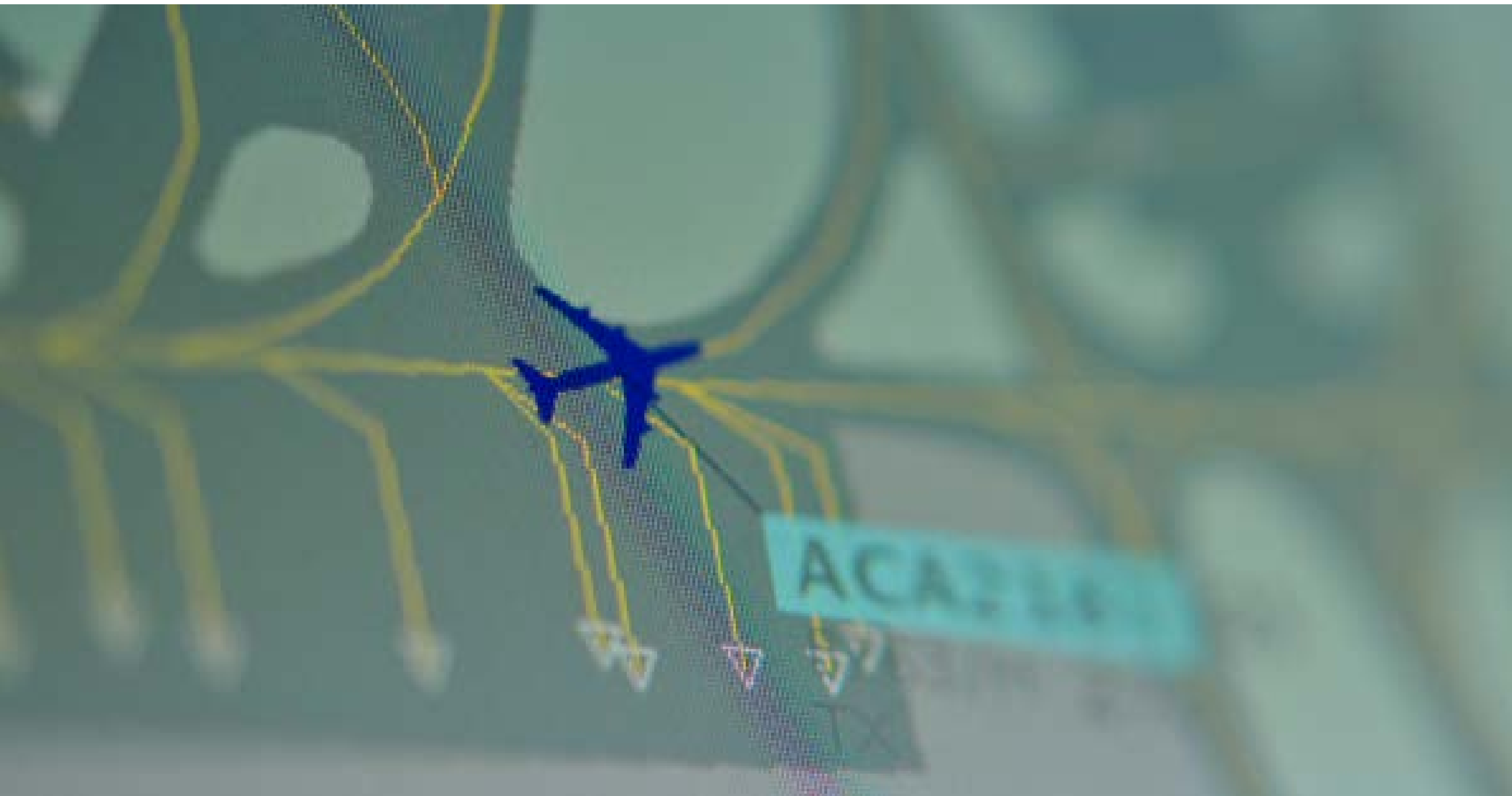
3.2.6 Military contribution to network performance

Aviation is a strong driver of economic growth, jobs, trade and mobility, and it is also key to enabling military air power to provide security and defence (36). Consequently, considerations relating to economic interest and to national security and defence need to be addressed taking a balanced approach.

As in civil aviation, military airspace requirements are also growing as a result of new manned and unmanned aircraft, weapons systems and concepts of operations stemming from changing geo-strategic challenges [37]. Furthermore, greater mobility of forces within and beyond the EU will enhance European security by enabling EU Member States to act faster, in line with their defence needs and responsibilities, in the context of both common security and defence policy missions and operations and national and

[36] Military aviation strategy in the context of SES, 2017.

[37] Joint declaration by the President of the European Council, the President of the European Commission, and the Secretary General of the North Atlantic Treaty Organisation, 8 July 2016 (http://www.consilium.europa.eu/media/21481/nato-eu-declaration-8-july-en-final.pdf).



multinational activities (e.g. through the EU or NATO) [38].

To fulfil requirements emerging from new military concepts of operation, military aviation requires due prioritisation and facilitation to conduct operations, training, air policing and air defence missions, without prejudice to the safety of civil air traffic, for day-to-day training operations and when transiting to major crisis areas.

Because such facilitation should have recourse to the development of new technologies and procedures, it is therefore crucial that military aviation is fully associated from the outset with the whole SESAR life cycle to exploit all existing civil-military synergies. For example, dual-use solutions can contribute to ensuring both the safety, regularity and efficiency of the global aviation system and compliance with requirements for military air operations and training.

[38] European Commission, Joint communication to the European Parliament and the Council on the action plan on military mobility (JOIN(2018) 5 final), Brussels, 28.3.2018.

Civil and military system interoperability is the basis on which reuse of existing military capabilities can be enabled. It is considered vital that recommendations and regulations at global and regional levels should specify performance target objectives rather than equipage requirements. Moreover, the military should maintain the ability to protect the confidentiality of mission-critical information. A resilient and robust ATM system, including a data-sharing network and relevant cyber-protection and cyber-resilience measures, is essential to ensure that the military can perform its duties 24/7, notably in the event of a crisis.

Enhanced airspace management (ASM) through concepts going beyond flexible use of airspace and using enhanced segregation features (e.g. variable profile areas and dynamic mobile areas) to support the dynamic configuration of airspace and mission trajectory management will contribute to the efficiency with which both civil and military requirements are met, while improving network performance. Measuring the effectiveness of the implementation of advanced flexible use of airspace by choosing appropriate metrics for a civil-military approach will contribute to ensuring military mission effectiveness and to overall ATM performance gains with an expected proactive military contribution. It is also recognised that an important means of coping with future civil-military needs will be a rationalised CNS infrastructure that could reduce costs and provide a solution for spectrum congestion, including for the military. In this context, virtualisation, automation and digitalisation, as well as AI technologies, will be major enablers.

In the future, manned and unmanned military training and operations will be conducted seamlessly across Europe owing to the implementation of harmonised procedures and new standards and systems.

OPERATIONAL VIEW

This chapter mainly addresses how the vision presented in Chapter 2 and the performance ambitions set out in Chapter 3 are supported by the innovation pipeline, bringing R&D projects to maturity and deployment stage. Having first summarised the SESAR target concept, which is in the pipeline towards deployment (see Section 4.1), the chapter then describes the nine essential operational changes (EOCs) — the essential game changers — triggering structural alterations to the European ATM. It also provides an overview of the prioritised SESAR Solutions that are in deployment and development to support the delivery of the vision up to phase C (Section 4.2).

The concept of SESAR Solutions. The SESAR R&D programme identifies, assesses and validates technical and operational concepts in simulated and real operational environments. This process transforms concepts into specific SESAR Solutions, which are self-standing packages that aim to contribute to the modernisation and high performance of the European ATM system. This concept structures the R&D programme. To allow for easy identification by non-specialists and a sense of belonging on the part of key stakeholders, the solutions are grouped into four **key features**, making it possible to easily identify to what environment the solutions [39] relate.

These key features are:

High-performing airport operations;

Advanced ATS;

Optimised ATM network services;

Enabling aviation infrastructure.

For ease of reading for stakeholders and investors, Section 4.2 is complemented by Annex A, which provides a list of all the solutions currently delivered or in development, mapped against both EOCs and key features.

In order to fully deliver the vision and in particular phase D, the digital European sky, additional R&D will be needed beyond

[39] All the solutions that the programme has been, or is, working on are presented in the SESAR Solutions catalogue, where they are categorised according to these four key features, thus ensuring that the catalogue is easy for stakeholders and investors to read. The catalogue is publicly available, regularly updated, widely distributed in print form and available from the SJU website (https://www.sesarju.eu/solutionscatalogue).

the current SESAR programme. The key areas where future R&D will be required are specified in Section 4.3.

As a major ATM modernisation programme, SESAR shares responsibility for and interest in harmonisation as a means of ensuring safe, efficient and seamless global interoperability. Section 4.4 puts the European R&D driven by SESAR into a global context, describing its contribution to the setting of the International Civil Aviation Organisation's (ICAO's) Global Air Navigation Plan (GANP) as well as Europe's cooperation with other regions of the world.

Modernisation of the European ATM, in particular when driven by digitalisation and automation, cannot be achieved without taking full account of the role of the human and the human interface with the machine. This is addressed in Section 4.5.

Moves towards automation and digitalisation require additional efforts to guarantee the security, and in particular cybersecurity, of the system, in order to preserve and if possible further enhance the level of safety. These efforts are detailed in Section 4.6.

4.1 SESAR TARGET CONCEPT — IN THE PIPELINE TOWARDS DEPLOYMENT

The SESAR target concept aims to deliver an ATM system for Europe that is fit for the 21st century and capable of safely and efficiently handling the growth and diversity of air traffic while improving environmental performance. This target concept relies on a concept of operations underpinned by technologies that enable improvements at every stage of the flight. Put simply, the target concept envisages the integration of all aerial vehicles, with higher levels of automation and digital connectivity, coupled with more automated support for the management of air traffic. In this new paradigm, aircraft will fly their optimum trajectories, relying on improved data sharing between aircraft and the ground infrastructure using mobile, terrestrial and satellite-based communication links. The SESAR concept also addresses airport operational and technical system capacity and efficiency, introducing technologies such as satellite-based tools for more accurate navigation and landing, and mobile communications to improve safety on the airport surface. Meanwhile, data analytics and better data sharing through SWIM allow for dynamic flight planning and more predictable airport operations, with their full integration into the overall ATM network. Service provision will be made more flexible and resilient through the implementation of a virtualised architecture, which will support the provision of additional capacity where and when it is needed.

TBO are at the core of the SESAR target concept, providing high predictability and accuracy of the trajectory during planning and execution of the flight, with airborne and ground actors sharing consistent information throughout the business/mission trajectory life cycle. On the ground, flight operations centres (FOCs) and wing operations centres (WOCs), the Network Manager, airports and ANSPs will share trajectory information through SWIM.

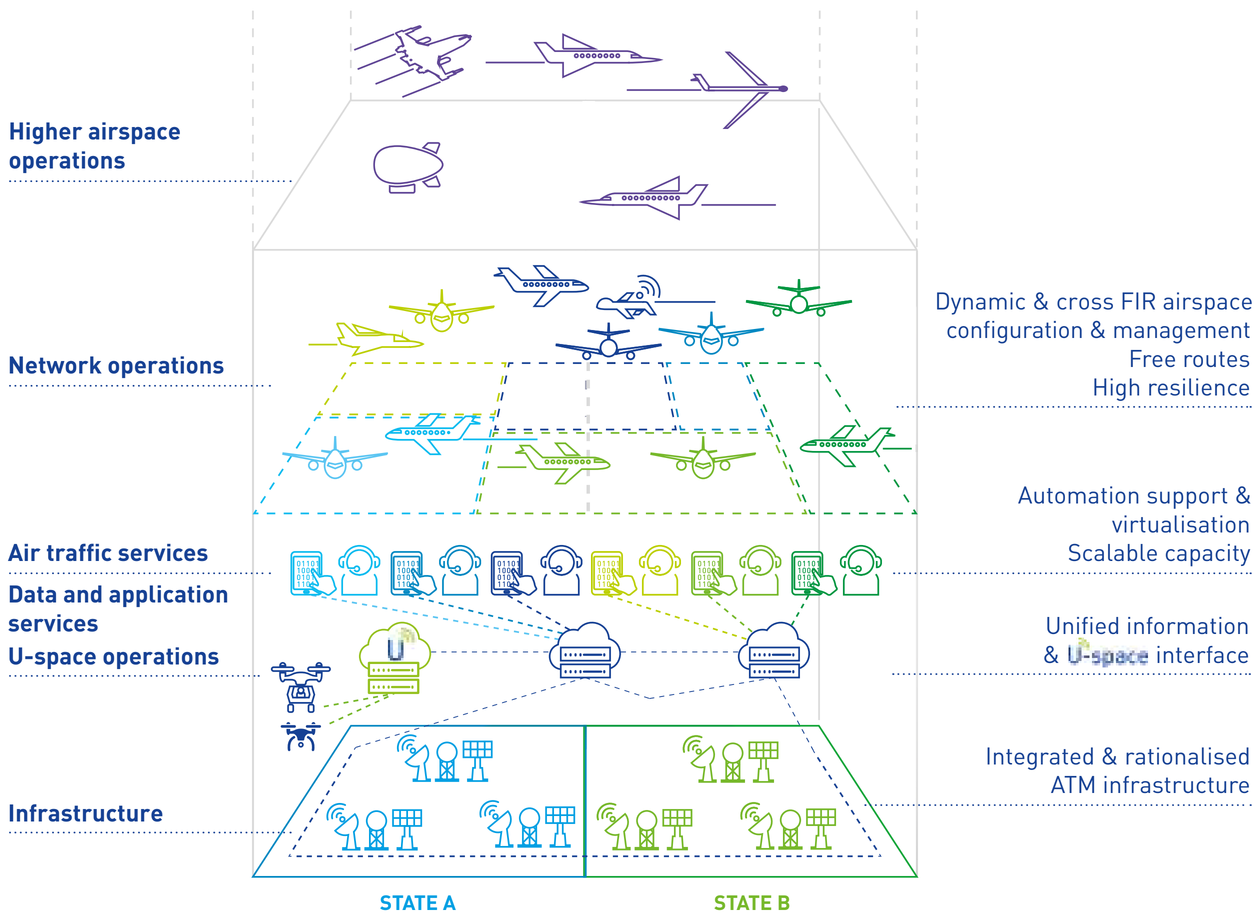
Technological improvements to civil and military airborne and ground systems will be essential to the realisation of the SESAR target concept. Standardised and interoperable systems will enable civil and military airspace users, manned and unmanned operations, to interoperate seamlessly. Area control centres will be connected to a common, virtualised ATM data service layer.

The target concept also addresses the airspace and trajectory management needs of the military community, with the aim of ensuring the smooth flow of civil traffic while meeting states' needs for flexible training and security-related operations.

The SESAR target concept is designed to support not only the commercial airline community, recognised as vital to the economic performance of Europe, but also all other stakeholder groups, such as business aviation, general aviation rotorcraft, and RPAS, which will be able to operate seamlessly alongside manned aviation.

The progressive implementation of the SESAR target concept will be supported by enabling a seamless European en-route airspace. This new architecture (**FIGURE 11**) is incorporated in the notion of the Single European Airspace System, in which resources are connected and optimised across the network, leveraging modern technology through a data-rich and cybersecure connected ecosystem. In this environment, service providers would be able to collaborate and operate as if they were one organisation, with both airspace and service provision optimised according to traffic patterns. This architecture is fully compatible with the overall SESAR target concept of a more profound change in core ATM functionality, capable of supporting traditional airspace users and new forms of traffic, such as RPAS, supersonic flights and higher airspace operations.

FIGURE 11. THE TARGET ARCHITECTURE



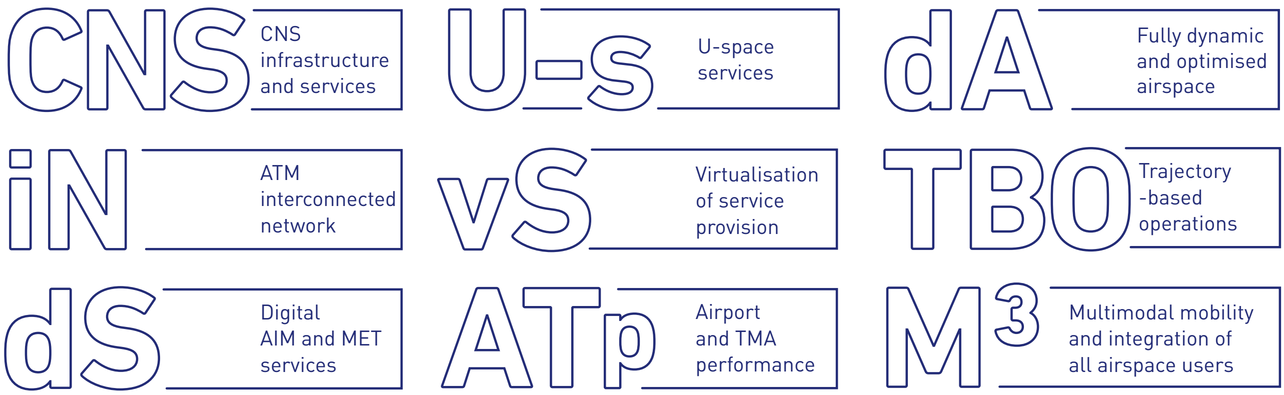
New levels of digital connectivity and automation will enable the creation of an entirely new aviation category: U-space. With the exponential growth in the use of drones across Europe, there is an urgent need to put in place a new UAS traffic management (UTM) system that supports the safe and effective integration of drone operations with manned aviation. This new system is called U-space, and will involve a staged approach to the definition and implementation of services, procedures and technology to enable drone operations. U-space implementation starts by enabling simple, local operations and will lead to the full, highly automated operation of fleets of drones performing a wide range of aerial tasks.

The role of the human, and its continued importance is recognised in the target concept, which takes into account the necessary balance between the efficiency created by automation and human capabilities. For the foreseeable future, human decisions will need to take primacy over systems, regardless of the level of automation.

The forecast increase in traffic requires that the aviation industry rigorously consider its environmental impact. Through efficient management of airborne and surface routing and associated procedures, the SESAR target concept seeks to reduce the impact of aviation on the climate, reduce noise and put the health of aviation personnel and the wider European community as a whole on the research agenda.

It is important to remember that safety is the overarching concern of aviation and therefore is central in the development of SESAR Solutions. The solutions are supported by new tools designed to prevent or reduce the risk or loss of separation, to reduce the risk of runway excursion, to improve runway condition awareness, to alert for taxi non-conformance and to avoid collisions on the airport surface. Safety nets are being updated to secure operations within the new SESAR environment through the development of advanced collision-avoidance tools, taking advantage of additional information and improving compatibility between all AUs, manned and unmanned.

Essential operational changes EOCs



4.2 ESSENTIAL OPERATIONAL CHANGES

The EOCs described below are the nine essential game changers triggering structural evolutions of the European ATM. They will be required to deliver the SESAR vision up to and including its Phase C, the defragmentation of European skies through virtualisation, and will enable the delivery of the SES objective of implementing 'more sustainable and better performing aviation' ([40]).

The EOCs are not independent of each other. In particular, some of them are closely linked in terms of delivering en-route performance and have driven the definition of the target architecture, while others bring essential changes to other parts of the system. As we move towards the vision, they are expected to interrelate as detailed below.

- Progress towards a service-oriented ATM requires all parties to be connected to a high-bandwidth, low-latency network infrastructure based on internet protocol (IP). This is part of delivering **CNS infrastructure and services**.

- With basic connectivity in place, a service delivery infrastructure needs to be put in place to connect all stakeholders in collaborative decision-making processes to enable the **ATM interconnected network**.

- The core functions of the **ATM interconnected network** are a basic prerequisite for **TBO** and **fully dynamic and optimised airspace**, as well as an enabler of the **virtualisation of service provision**.

- **Virtualisation of service provision** is a must to make the most efficient use of ATM data-processing resources, but it can deliver value only if it is accessed as a service irrespective of its geographical location.

- **Virtualisation of service provision** is also an essential element for decoupling the current ANS provision from the supporting infrastructure and should allow for a reduction in the number of deployment locations for new SESAR Solutions, thus significantly reducing deployment complexity and future investment costs.

- **TBO** require complex trajectory information synchronisation mechanisms to benefit from a deployment environment that is less fragmented than today.

- Interoperable **digital AIM and MET services** are an essential precondition for **TBO**, and therefore need to be deployed in advance of TBO.

([40]) European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions — Single European Sky II: towards more sustainable and better performing aviation (COM(2008) 389 final), Brussels, 25.6.2008.

- **Airport and terminal manoeuvring area performance** for all operational conditions is and will remain a critical element for the entire network. Continuous improvements will be required, with some solutions exploiting the **ATM interconnected network** while others benefit from the **virtualisation of service provision**.

- The change to **fully dynamic and optimised airspace** is best implemented in an airspace that is already optimised for traffic flows and where service provision is being virtualised. Airspace optimisation provides urgently needed capacity benefits while providing an airspace context that is appropriate for fully dynamic airspace and the implementation of **TBO**.

- The **first U-space services** will start to be rolled out to enable the subsequent integration of various new vehicles. With the **ATM interconnected network** in place, **U-space services** will play an important role in the move towards **multimodal mobility and integration of all airspace users**.

Each EOC is supported by SESAR Solutions and deployment scenarios [41] contributing to its achievement. The following subsections provide a short description of each EOC and the prioritised solutions or deployment scenarios supporting it, according to their degree of maturity:

- **In deployment:** a growing number of Solutions are already in deployment — either through regulation or voluntary initiatives at network, regional or local level — or are mature and available for deployment. They are paving the way for the delivery of the SESAR vision.

- **In the development phase or in the pipeline towards deployment:**
  - **solutions approaching maturity:** other solutions, appropriately clustered in deployment scenarios, are still at the development stage but expected to reach maturity and thus the industrialisation phase by the end of 2020;

[41] A deployment scenario is a solution or group of solutions that belong to the same architectural capability. It may include deployment synchronisation aspects that will create synergies and additional benefits in the expected operating environment.

- **key R&D activities:** they are the prioritised candidate solutions under development within the SESAR programme, expected to deliver the end of phase C of the vision.

Section 4.3 describes the R&D that will be required beyond the existing SESAR programme to deliver phase D of the vision, the digital European sky.

An exhaustive list of all solutions and deployment scenarios linked to the EOCs is provided in Annex A; the list also includes, going beyond the prioritised solutions and key R&D activities, additional mature solutions and ongoing R&D activities, less crucial to achieving the vision but still valuable, or even required, to improve ATM performance at network, regional or local level.

4.2.1 CNS infrastructure and services

The historical national ownership of CNS infrastructure, as well as the need to support a variety of heterogeneously equipped airspace users (civil and military), has led to an inefficient distribution of equipment when taking performance needs in relation to air traffic into consideration. In addition, some technologies still in operation have overlapping capabilities and, in a context of steady growth, may not be able to provide the required performance to deliver the SESAR vision. Therefore, the main challenge is to optimise the infrastructure and rationalise it both on the ground and in the air. The development and implementation of new technologies supported by satellite infrastructure will offer opportunities for Europe to reduce significantly its annual operating and investment budget in CNS while improving efficiency in the use of scarce resources, especially spectrum. The development of ATM, with the use of virtualisation and innovative concepts of operations, will support the move towards a service-oriented architecture, in which CNS service providers and ANSPs, as consumers of these services, may be different entities. This will enable more capacity in the medium term to meet the current and expected traffic demand. It will also address the future needs of all airspace users, including new entrants, be they low-altitude drones or very high-altitude aircraft.

4.2.1.1 Description of the essential operational change

Changes in the area of CNS will be driven by a service-based approach and a performance-based approach. This will enable the decoupling of CNS service provision from ATS and ATM data services. This change will make the European ATM system more flexible and resilient, allowing scalability.

FIGURE 12. **CNS AS A SERVICE**

Through a **service-based approach**, CNS services will be specified through contractual relationships between customers and providers, with a clearly defined, European-wide set of harmonised services and level of quality. This approach will create business opportunities for those providing affordable services, with a strong incentive for service providers to compete resulting in cost-efficient services. The progressive introduction of a service-based approach to CNS will enable the virtualisation of ATM (consisting in decoupling the provision of ATM data services from ATS) and will enable ANSPs to make implementation choices about how new services are provided. A service-based approach to CNS (as illustrated in **FIGURE 12**) should provide a strong incentive for service providers to cooperate across national boundaries and to optimise the use of technologies and the geographical distribution of equipment (and hence optimise spectrum use). It will also provide a better environment for the integration of new CNS services, such as space-based automatic dependent surveillance broadcast (ADS-B) and satellite communications.

The **performance-based approach** will see a move from system/technology-based operations, where systems/technologies are prescribed, towards performance-based services, which specify the ambition to be achieved within a specific environment.

It is anticipated that this service-based and performance-based approach will favour potential technological/functional synergies across communication (COM), navigation (NAV) and surveillance (SUR), taking advantage of common system and common infrastructure capabilities for the ground, airborne and space segments. From a service standpoint, the boundaries between the different domains will disappear progressively as the infrastructure moves to an integrated digital framework. It will be the most cost-effective solution for providers and users. Technologies will evolve over time without requiring the operations themselves to be revisited, as long as the requisite performance is achieved by the system.

The future CNS infrastructure will be based on an integrated CNS backbone comprising the multilink Pan-European Network Service, a global navigation satellite system (GNSS) and ADS-B. This integrated backbone will be complemented by a minimum operational network (MON) ([42]), composed of legacy infrastructure systems (e.g. distance-measuring equipment (DME) and an instrument landing system (ILS), rationalised to provide efficient support and operate as a backup for the integrated backbone. The MON will provide safe transitions in and out the integrated modes, as well as a safe, stable operation if required.

During the transition to the SESAR vision, the degree of rationalisation will increase with the development of CNS services.

([42]) Minimum operational network: a fair rationalisation of CNS legacy infrastructure down to a point where it can still operate as a backup or provide an efficient support as a secondary technology, in the event of loss of GNSS, for example.

FIGURE 13. **CNS SERVICE TRANSFORMATION**

CNS transformation

FROM	TO
— 3 separate CNS domains with conventional technology and low integration	— One lean and efficient infrastructure with state-of-the -art technology
— Technology/system-based CNS framework — Fragmentation costs and costly infrastructure — Poor business opportunities	— Service and performance-based CNS framework — Cost efficient — Large business opportunities
— Voice primary mainly based on analogue communication — Narrow band connectivity	— Data-link primary mainly based on digital communications — Broadband connectivity — A/G SWIM supporting automatic trajectory sharing & trajectory-based operations — Support for digitalisation, automation and remote provision of ATM data & tech service
— Conventional navigation ground-based navaids — ILS-based	— Multi-constellation GNSS for high-availability primary means of navigation — SBAS primary for Cat I / GBAS primary for Cat II/III
— Exposed and vulnerable	— Robust & resilient — Cyber secure
— Poor civil/military interoperability with low dual use	— High civil/military interoperability with maximal dual use
— Saturated spectrum with sub-optimal spectrum utilisation — Reactive process against threats	— Available spectrum and efficient use of spectrum — Proactive process and long term view

Under this approach, the introduction of new capabilities follows an integrated CNS roadmap, which provides robustness and new opportunities to enable performance-based and service-based CNS and facilitate ATS while ensuring civil-military interoperability.

Performance requirements can be expressed with respect to various airspace user types and various environments, with the aim of optimising overall performance with no degradation for the least capable airspace users.

The EU strategies and policies with respect to space-related technologies [43] encourage the uptake of solutions that are enabled by the European Geostationary Navigation Overlay Service (EGNOS) and Galileo, Europe's satellite navigation system. In this respect, the 2018 EU air navigation strategy developed by the European Commission and presented to the Single Sky Committee in the context of the PBN implementation roadmap confirms the availability of PBN applications from 2015. It states that, in order to ensure necessary independence when GNSS is the primary means of navigation, Galileo and EGNOS will become GNSS components required in the EU, for the multifrequency, multi-constellation GNSS system.

For end-users, the technological solutions will be packaged or merged in a way that guarantees availability, integrity, safety and security, and performance requirements, as mandated by relevant authorities.

[43] European Commission, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions — Space strategy for Europe (COM(2016) 705 final), Brussels, 26.10.2016; Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, OJ L 212, 22.8.2018, p. 1-122.

4.2.1.2 Related SESAR deployment and development activities

4.2.1.2.1 In deployment

The following mature deployment scenario supports short- and medium-term CNS rationalisation.

CNS rationalisation will facilitate network optimisation following implementation of new functionality and/or technologies. For navigation, the availability of GNSS services enabling PBN services creates opportunities to rationalise and optimise the use of the non-directional beacon (NDB) and very high-frequency (VHF) omni-range and distance-measuring equipment (NDB, very high-frequency omnidirectional radio range (VOR), DME) infrastructure, and the availability of ground-based augmentation systems/ satellite-based augmentation systems (GBAS/SBAS) creates new operational conditions for approach and landing operations and valid alternatives to an ILS for some airports. CNS rationalisation will be supported by the use of an MON of the legacy infrastructure to a level suitable for use as a fall-back in the event of, for example, loss of GNSS. For surveillance, the implementation of an optimal mix of ADS-B, wide-area multilateration (WAM) and mode S secondary radars will make it possible to decommission all secondary surveillance radar (SSR) mode A/C ground stations.

The following SESAR Solutions support CNS rationalisation.

- ATS datalink using satcom (satellite communications) class B offers a first option for the future communications infrastructure (FCI) for ATS datalink using existing satellite technology systems to support initial four-dimensional (i4D) datalink capability and provide end-to-end air-ground communications for i4D operations, connecting aircraft and ATM ground systems.

- ADS-B surveillance of aircraft in flight and on the surface consists of enhanced functionalities and interfaces (e.g. improving surveillance data processing and distribution to facilitate tracking of aircraft in flight and on the surface). These enhancements are required to ensure compliance with new applications of ADS-B for radar airspace and airport surveillance, and other emerging requirements such as security requirements.

- Localizer performance with vertical guidance (LPV) approaches using Satellite-Based Augmentation System (SBAS) as alternative to ILS Cat I. It provides the airspace users stable approach options with the lowest minima relative to non-precision instrument approach and facilitates advanced arrival procedures.

- Precision approaches using Ground-Based Augmentation System (GBAS) category II/III maximises the benefits of GBAS technology for visibility down to category II/III minima to mitigate the impact of adverse weather conditions on airport capacity, as well as to reduce delays and disruption for airspace users.

4.2.1.2.2 In the development phase or in the pipeline towards deployment

SOLUTIONS APPROACHING MATURITY

- Enhanced airborne collision avoidance for commercial air transport normal operations (ACAS Xa): this is an airborne collision avoidance system that takes advantage of optimised resolution advisories and additional surveillance data but will not change the cockpit interface (i.e. it uses the same alerts and presentation as the current traffic collision avoidance system).

- Alternative position, navigation and timing (A-PNT): in the short term, this provides fallback capabilities in the event of GNSS unavailability, using an optimised DME navigation aids infrastructure as a backup.

KEY R&D ACTIVITIES

The CNS services evolution deployment scenario includes the following.

- Integrated CNS and spectrum addresses CNS cross-domain consistency in

terms of robustness, spectrum use and interoperability, including civil-military aspects, through the provision of a global view of future CNS services, as well as the definition of the future integrated CNS architecture and the CNS spectrum strategy.

- FCI services address the provision of digital communication services (IP-based data and digital voice). It supports future ATS and airline operations centre (AOC) services with demanding high air-ground and air-air communication capacity and high performance. It will allow the real-time sharing of 4D trajectories and timely access to ATM data and information services and will enable network-centric SWIM architectures. It manages, in a secure way, different subnetworks. It also integrates the services provided by open networks needed for hyper-connected ATM.

- The FCI terrestrial datalink and A-PNT enabler, L-DACS (L-Band Digital Aeronautical Communication System), constitutes the future terrestrial air-ground and air-air datalink solution to support increasing ATM performance requirements. The development and standardisation of L-DACS technology will continue. The system will address both avionics and ground implementation.

- Future satellite communications datalink class A performance will enable more ATM concepts and services to emerge. It aims to provide global interoperability based on an international communications standard that ensures that aircraft equipped with a standard terminal will be able to communicate anywhere using compatible satellite systems. In addition, it is expected to ensure lower costs for aircraft equipage and communication services.

- Dual-frequency multi-constellation (DFMC) GNSS/SBAS and GBAS address the move towards resilient and performance-based navigation in all phases of flight, taking advantage of a dual GNSS constellation (GPS and Galileo). In particular, for the approach phase, this will includes the development of GBAS approach service type F

(GAST-F), based on multi-constellation multi-frequency GNSS. Finalisation of the development of GAST-F CAT II/III (these are ICAO categories of precision approach and landing) and DFMC SBAS is expected to maximise the benefits of satellite-based technology for achieving approach in low-visibility conditions down to CAT II/III minima for GBAS and lateral precision with vertical guidance down to 200 ft for SBAS (LPV 200).

- In the long term, the aim is to develop A-PNT systems capable of providing better performance in comparison with the short-term solution (based on DME-DME) and supporting PBN / required navigation performance (RNP) operations using alternative technologies in the event of a GNSS degradation or outage.

Hyper-connected ATM: this deployment scenario considers the possibility of using commercially available services, delivered using open technologies (e.g. 5G networks, open satcom), to support demanding and broadband applications, including in support of ATM (and as such providing services to the FCI), for U-space operations and other uses (e.g. engine maintenance).

4.2.2 ATM interconnected network

Today's European ATM system comprises a wide variety of applications developed over time for specific purposes. The interfaces used by these applications are custom-designed; they are developed, managed and maintained individually and locally, at significant cost and with suboptimal performance. There is a strong case for standardisation of the ATM system interfaces.

Through the implementation of a collaborative network for planning and decision-making, the implementation of the ATM interconnected network enables the implementation of flight- and flow-centric operations. For the provision of common network situational awareness and enhanced DCB tools, the Network Management function will require further improvements to ATFCM and ASM processes and systems, enabling a collaborative approach in the context of flow and network management and reconciling requirements for increased dynamic capabilities and predictability. Particular attention will need to be paid to the subject of multiple constraints resolution and network impact assessment. There will be also a need for further improvements in network complexity management, ATFCM scenario management and performance monitoring.

4.2.2.1 Description of the essential operational change

The ATM collaborative network enables all relevant stakeholders to participate in collaborative decision-making processes in a transparent framework, and to negotiate their preferences and reach agreements that benefit not only one but all of the

stakeholders involved, thus contributing to the performance of the entire network. The collaborative network operations plan (NOP) will provide, in a continuum from planning to execution, a real-time visualisation of the evolving network planning environment, leading to network stability, increased capacity and increased efficiency.

Further improvements to DCB tools and ATFCM processes through collaborative network operational planning are needed, not only to enhance network performance but also to allow the integration of the ATFCM and ATC planning functions. Integrated local DCB processes are intended to improve situational awareness through the seamless integration of local network management with extended ATC planning and arrival management activities. The network prediction and performance processes are intended to ensure increased efficiency by assessing the performance of network operations, enabling stakeholders to evaluate the impact of their intentions and decisions.

Collaboration among stakeholders, in real time, will be improved by extended airport integration with ATM network planning, multi-slot swapping and a user-driven prioritisation process, allowing airspace users to make a priority order request for flights affected by delays and to share preferences with other ATM stakeholders, in capacity-constrained situations and in non-constrained situations, during the planning and execution phases. This will increase the flexibility available to airspace users for addressing unexpected business needs. The integration of airport and network planning targets the timely exchange of relevant airport and network information, resulting in a common situational awareness and improving network and airport planning activities, as well as overall operational performance. The collaborative airport and network processes are expected to deliver arrival and departure predictability for both airports and the network in all traffic conditions.

The infrastructure component of the ATM collaborative network needs to be based on the implementation of a service delivery infrastructure, providing accurate information using common standards. Global interoperability and standardisation are essential, and this EOC is expected to be an important driver of new and updated standards. It should be based on service-oriented architecture driven by analysis of business processes and needs. The ATM collaborative network is to be developed, packaged and implemented as a suite of interoperable services that can be used in a flexible way within multiple systems in several business domains, delivered using open and standardised mainstream technologies.

4.2.2.2 Related SESAR deployment and development activities

4.2.2.2.1 In deployment

As part of the PCP, the following have been deployed:

- initial SWIM [44];
- calculated take-off time to determine the target time of arrival (TTA) for ATFCM purposes;
- collaborative NOP;
- automated support for traffic complexity assessment;
- enhanced short-term ATFCM measures.

The following mature SESAR Solutions are proposed for deployment.

- Enhanced ATFM slot swapping: this aims to improve the current NM/AU processes and make it possible to prioritise flights during pre-tactical operations. It facilitates the identification of possible swaps of a regulated flight with another flight, regulated or not, and allows a significant reduction in the rate of rejection of swap requests.
- Airport integration into the network: this deployment scenario is supported by a Solution that targets small and medium-

[44] As part of initial SWIM, the IOP solution is critical to enable the European aviation infrastructure to evolve towards higher levels of interoperability, digitalisation and automation, supporting trajectory-based operations.

sized airports and aims to enable the integration of estimated departure times, as well information about expected delays or cancellation of flights. This aircraft departure planning information should provide the ATM network with a more accurate view of the traffic and thus support predictability.

- Collaborative airport (airport operations plan - network operations plan (AOP - NOP) phase 2): this deployment scenario is supported by a solution making it possible to interface landside with the ATM network. In this scenario, airport operations planning, monitoring, management and post-operations analysis tools and processes are built into the AOP and the airport collaborative decision-making process for normal, adverse and exceptional operating conditions. **TTA is derived from the AOP and used by the NM to balance arrival demand and capacity, thus facilitating arrival management processes during the en-route phase**. These processes are fully compatible with the NOP and SWIM-based services.

4.2.2.2.2 In the development phase, in the pipeline towards deployment

SOLUTIONS APPROACHING MATURITY

- SWIM TI (SWIM technical infrastructure) purple profile for air-ground advisory information sharing: this supports ATM operational improvements that depend on air-ground information exchanges to enable better situational awareness and collaborative decision-making. The activities include the specification of the technical architecture and functions that are required to achieve full interoperability between air and ground SWIM segments and meet the safety and performance requirements for airborne operations.

KEY R&D ACTIVITIES

- SWIM TI purple profile for air-ground safety-critical information sharing: this aims to allow the distribution of safety-critical information through air-ground SWIM infrastructure and aeronautical telecommunications network-IP suite networking, rather than legacy point-to-point contracted services. Technical specifications will be defined to support safety and security requirements, allowing the exchange of safety-critical information.

- Enhanced network traffic prediction and shared complexity representation: the objective is to improve the accuracy of the Network Manager's traffic predictions from the medium-term planning phase (2 days before operations) to execution, relying in particular on new trajectory management features such as the preliminary flight plan. The Solution will adapt existing methodologies and

algorithms for demand prediction and regional complexity assessment.

- Network optimisation of multiple ATFCM time-based measures: this involves improving efficiency and reducing the adverse impact of multiple regulations affecting the same flight or flow. It also involves exploring the relationships between the DCB regulations and their interaction through flights to quantify the network effect of those interactions. The key to this is identifying and eliminating regulations that have a negative impact on network performance.

- Collaborative network performance management: this aims to provide a common framework and toolbox for the other solutions and actors, making it possible to assess network performance in the pre-tactical and tactical phases of network management. It will involve developing transparent and shareable network performance indicators, and network state monitoring and prediction tools. This will support the Network Manager operations centre (NMOC) through greater supervision and awareness, as well as network performance "what-if and what-else" capabilities.

- Digital collaborative airport performance management: this addresses digital data management for airport performance, through the development and validation of rationalised predictive datadriven dashboards, fed with all landside and airside leading key performance airport indicators and covering total airport management processes. This will enable stakeholders to proactively identify demand and capacity imbalances, their time frames, locations and the trajectories affected, and solve them supported by "what-if" capabilities. The Solution uses data and video analytics, big data and machine-learning techniques.

- Enhanced collaborative airport performance planning and monitoring: this aims at improving the collaborative airport performance planning and monitoring processes, in particular through the inclusion in the airside processes of the relevant landside (passengers and baggage flows) process outputs, by taking into account connectivity and multimodality aspects, and through the extension of turnaround monitoring within the airport operations centre. The goal is to achieve full and seamless interoperability with AU operational systems and to improve connectivity between regional airports and the NMOC.

- Collaborative framework for managing delay constraints on arrivals: this aims to facilitate the integration and coordination of 4D constraints from various stakeholders (airports, ANSPs, AUs and the NM) to ensure the stability and high performance of the network. Furthermore, it enables airspace users to prioritise their important flights to reduce the impact of ATM planning constraints on the cost of their operations. It streamlines the prioritisation process during the planning phase and, instead of routinely using regulations to resolve demand and capacity imbalances on arrivals, allocates target times. AU prioritisation is key to the process of selecting flights for allocation of target times.

- SWIM TI green profile for ground-ground military information sharing: this solution is intended to enable ground-ground civil-military coordination through SWIM profiles. It includes (cyber)security and (cyber)resilience aspects and fills the gap between existing ground-ground profiles and what is required to fully support SWIM-based civil-military coordination and cooperation, especially in terms of (cyber)security.

- Digital integrated network management and ATC planning: this aims to fill the gap between management of traffic flows at network level and control of flights in individual sectors, through the development and integration of local functions and associated tools, roles and responsibilities to address DCB with the network management function. The Solution will provide an automated interface between local flow management, the NM and ATC planning to assist controllers in reducing traffic complexity, traffic density and traffic flow problems.

4.2.3 Digital AIM and MET services

The ability to move to full TBO in a collaborative environment strongly depends on the sharing, between all actors involved (aircraft, AOCs, WOCs, ATS units (ATSUs), ADSP, and NM), of a similar picture of the environment in which the flights operate. This requires that the full range of relevant aeronautical and meteorological information be shared and available simultaneously to all actors. With the need to use airspace and other ATM resources in a dynamic way and to ensure efficient performance delivery at all times, network access to up-to-date aeronautical and meteorological information, with minimum delay and from anywhere, will be a must.

4.2.3.1 Description of the essential operational change

The digitalisation of AIM and MET services will enable the implementation of services to provide static and dynamic aeronautical and meteorological information in digital form, useable by ATM systems and human operators. The output is a SWIM-compliant dynamic data set, subsets of which can be retrieved by individual requests for specific geographical areas, attributes or functional features. These

services will also allow the on-board acquisition, processing and distribution of AIM, MET and other operational information, including the interpretation and representation of this information within the aircraft.

4.2.3.2 Related SESAR deployment and development activities

4.2.3.2.1 In deployment

The following mature SESAR Solution is proposed for deployment.

- Digitally enhanced briefing: this solution includes the improvement of the quality and usability of the aeronautical and meteorological information presented to the pilot, flight dispatchers and ATCOs during all phases of flight, through the use of digital aeronautical data (including a digital notice to airmen and digital meteorological data).

4.2.3.2.2 In the development phase, in the pipeline towards deployment

SOLUTIONS APPROACHING MATURITY

Improved aviation AIM and MET services through automation and digitalisation: this deployment scenario addresses new services such as static aeronautical data service and aeronautical digital map service functions that will provide static and dynamic aeronautical data in digital form, to be used by various ATM systems (e.g. safety nets). The output is an aeronautical information exchange model-compliant data set, subsets of which can be retrieved by individual requests for specific geographical areas, attributes or functional features.

KEY R&D ACTIVITIES

Aircraft as an AIM/MET sensor and consumer: this Solution addresses the application of information made available by the aircraft (e.g. aircraft meteorological data, information derived from ADS-C, CNS status information) and improved use of MET and AIM information by airspace users. It makes it possible to increase AUs' situational awareness and improve strategic trajectory management and collaborative decision-making.

4.2.4 U-space services

The demand for UAS operations is steadily increasing, with the potential to generate significant economic growth and societal benefits. A drone traffic management system is needed to enable simultaneous drone operations in a safe and efficient manner in all types of airspace and especially urban areas. U-space is the framework designed in Europe in response to the urgent need to support the safe integration of drones into airspace, in particular but not only VLL airspace. U-space builds on ATM legacy, but it does not reproduce the current model for the provision of ATC services. By design, U-space is set to be scalable and will rely on high levels of autonomy and connectivity in combination with emerging technologies. U-space will encourage innovation, support the development of new businesses and facilitate the overall growth of the European drone services market while appropriately addressing safety, security and defence issues at EU level, in addition to respecting the privacy of citizens and minimising environmental impact.

4.2.4.1 Description of the essential operational change

U-space is an enabling framework including a set of new services along with specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. U-space is therefore not to be considered a defined volume of airspace, which is segregated and designated for the sole use of drones. U-space services will rely on a high level of digitalisation and automation of functions, whether on board the drone or as an element of the ground-based environment. Therefore, the implementation of the new services is associated with airborne capabilities and adequate/qualified ground infrastructure. Complementary infrastructure may be required if the existing ATM infrastructure does not meet requirements. The U-space framework includes a safe, secure, clear and effective interface with manned aviation, with ATM services / ANS providers and with the relevant authorities. U-space is capable of ensuring the smooth operation of drones in all operating environments and in all types of airspace. U-space operations will also enable national military airspace defence systems to react to any drone-related situation deemed critical to national security. U-space is developed and deployed in an agile way using short life cycles in which technologies are deployed as they become mature. This is done in four phases (U1, U2, U3 and U4), which serve as the basis for the gradual deployment of services.

4.2.4.2 Related SESAR deployment and development activities

R&D of U-space services is done in parallel with progressive and stepped implementation. Each step of U-space corresponds to a deployment scenario composed of a group of services and associated capabilities.

4.2.4.2.1 In deployment

- U-space U1 — foundation services: this deployment scenario provides foundation services, the main objectives of which are to identify drones and operators and to inform operators about known restricted areas. With the deployment of U1, more drone operations have been enabled, especially in areas where the density of manned traffic is low.

  The U-space foundation services include e-registration, e-identification and geo-awareness [45].

4.2.4.2.2 In the development phase, in the pipeline towards deployment

SOLUTIONS APPROACHING MATURITY

- U-space U2 — initial services: this deployment scenario relates to an initial set of services designed to support the safe management of beyond the visual line of sight (BVLOS) operations and a first level of interface and connection with ATM/ATC and manned aviation. This phase includes the establishment

[45] At the time of drafting this report, a draft Commission delegated regulation on unmanned aircraft systems and on third-country operators of unmanned aircraft systems and a draft Commission implementing regulation on the rules and procedures for the operation of unmanned aircraft, addressing these issues, had received a positive response from the EASA Committee and were in the Commission adoption pipeline.

of U-space service providers within a distributed and connected architecture. Where appropriate, U2 will make use of the existing infrastructure for ATM; new opportunities for drone operations will be enabled through the exploitation of technologies from other sectors. The range of operations at low levels will increase, including some operations in controlled airspace. Drone flights will no longer be considered on a case-by-case basis, and some BVLOS operations will become routine.

The U-space initial services will include at minimum the following: tactical geo-fencing, emergency management, strategic deconfliction, weather information services, tracking, flight planning management, monitoring, traffic information, drone aeronautical information management and procedural interface with ATC.

KEY R&D ACTIVITIES

- U-space U3 — advanced services: this deployment scenario will build on the experience gained in U2 and will unlock new and enhanced applications and mission types in high-density and high-complexity areas. New technologies, automated detect and avoid (DAA) functionalities and more reliable means of communication, including V2X [46], will enable a significant increase in operations in all environments and will reinforce interfaces with ATM/ATC and manned aviation. This is where the most significant growth in drone operations is expected to occur, especially in urban areas, with the initiation of new types of operations, such as air urban mobility.

  The U-space advanced services will include at minimum the following: dynamic geo-fencing, collaborative interface with ATC, tactical deconfliction and dynamic capacity management.

[46] V2X communications include V2V (vehicle to vehicle) and V2I (vehicle to infrastructure) communications.

4.2.5 Virtualisation of service provision

The traditional, historically established national provision of ANS is based on local implementation of the necessary capabilities. While this was technically the most feasible and appropriate solution when systems were originally built decades ago, this fragmentation of service provision generates cost-inefficiencies and a rigidity that makes it impossible to properly address the capacity challenges of today and tomorrow. Modern-day general-purpose communication and computer processing capabilities allow for better performing and more cost-efficient solutions, where physical processing capabilities no longer need to be close to the point of use. A reorganisation of physical assets among ANSPs, civil and military, should lead to facilitated data sharing, new synergies and more cost-efficient management of the ATM resource network. It should also facilitate effective interoperability between functional systems. With the support of virtual-centre technologies, it will be possible to provide services to one or more FIRs that may or may not be adjacent to each other, thus increasing the resilience and adaptability of the network with a view to delivering more capacity and cost efficiency.

4.2.5.1 Description of the essential operational change

The ability to provide ATS from a remote location is relevant in all operating environments: airport, TMA, extended TMA (E-TMA) or en route.

In TMA, extended TMA and en-route environments, the virtual-centre concept allows a geographical sector to be managed from any place subject to the availability of some services crucial for the provision of ATS, namely CNS, MET, aeronautical information services (AIS) and all data related to the flight plan. By using standardised operating methods, procedures and technical equipment, the services will be perceived as a single system from the user's perspective. This will be enabled by cloud-based data centres as well as data management processes and governance, provided remotely.

In airport environments, the remote tower concept supports several use cases that allow the provision of ATS from a remote tower centre (RTC), with a dynamic allocation of a number of physical aerodromes to remote tower modules. It offers new alternatives for the provision of tower-related ATS and in some cases reduces ANS costs. The integration of approach services to these airports through a remote virtual centre is also possible. Some solutions are already in deployment and R&D is continuing on more complex use cases.

4.2.5.2 Related SESAR deployment and development activities

4.2.5.2.1 In deployment

A growing number of SESAR Solutions using remote towers are in deployment, according to ANSPs' local business cases and decisions.

4.2.5.2.2 Related SESAR deployment and development activities

SOLUTIONS APPROACHING MATURITY

- Remotely provided ATS for multiple aerodromes: this includes the provision of aerodrome control services or aerodrome flight information services to more than one aerodrome by a single ATCO or aerodrome flight information service officer (AFISO) from a remote location, that is, not from a control tower located at the aerodrome. The ATCO (or AFISO) in this facility performs remote ATS for the aerodromes concerned.
- Virtual-centre concept: work station, service interface definition and virtual-centre concepts will provide an operating environment in which different ATS units, across different ANSPs, will appear as a single unit and will be subject to operational and technical interoperability. This will include development of the ATSU architecture, taking a service-oriented approach, with a focus on technical services and common interfaces.

KEY R&D ACTIVITIES

- Multiple remote towers and remote tower centres: this activity involves the remote provision of ATS from an RTC to a large number of airports. It includes the development of RTC supervisor and support systems and advanced automation functions for a more cost-efficient solution. It also covers the integration of approaches for airports connected to the remote centre and connections between RTCs with systems

for flow management, as well as the development of tools and features for flexible planning for all aerodromes connected to remote tower services.

- Human-machine interface (HMI) interaction modes for ATC centres and airport towers: this activity involves the development of new HMI interaction modes and technologies in order to minimise the load and mental strain on controllers, be they in the ATC centre or in the airport tower. The SESAR activities will make use of modern design and development approaches and methodologies such as modularity, service-oriented architecture and adaptive automation. The new HMI interaction modes include the use of in-air gestures, attention control, user profile management systems, tracking labels, virtual and augmented reality, etc.

- Delegation of services to ATSUs: this activity aims to explore the different possible way of delegating services to ATSUs based on traffic and/or organisational needs (either static on a fixed-time transfer schedule (day/night) or dynamic, for example when the traffic density is below or above a certain level) or on contingency needs. It has an operational thread, aimed at defining and validating the different types of delegation of services, and a technical thread, aimed at specifying the impact of the operational thread on the services defined in the virtual-centre concept.

4.2.6 Airport and TMA performance

Today, airport operations and airspace user operations, at and around airports, are already significant contributors to network-wide delays, largely due to structural capacity issues linked to operational and environmental issues, as well as bad weather conditions. By 2035, additional bottlenecks are expected to develop in locations where there is insufficient terminal airspace and/or airport capacity; approximately 0.9 million flights may be unaccommodated as a result of airport capacity limitations, while many airports will operate to a large extent at maximum capacity ([47]). Therefore, continuity of capacity delivery at airports and in TMAs and the need to improve the safety of operations at and near airports will become even more critical factors for the whole network.

([47]) Eurocontrol, 'Flight forecast to 2040 — challenges of growth', 2018 (https://www.eurocontrol.int/publications/flight-forecast-2040-challenges-growth-annex-1).

4.2.6.1 Description of the essential operational change

This EOC covers both changes to operations at airports and in TMA airspace that allow maintenance of operational capacity under limiting conditions and changes that allow an increase in operational capacity during normal operations. This includes improvements to the planning and execution of operations at and around airports, such as traffic sequencing, reduced separation, reduced and more predictable runway occupancy time, and enhanced management of taxiway throughput, for both arrivals and departures. This EOC also addresses the required coordination with TMA operations when aircraft sequencing for the runway begins, and, in addition, with extended arrival management in en-route airspace. It also includes solutions that increase the safety of operations and seeks to reduce environmental impact at or near airports. Enhanced navigation and greater accuracy in low-visibility conditions on the airport surface need to be made possible by the introduction of new airborne CNS capabilities.

4.2.6.2 Related SESAR deployment and development activities

4.2.6.2.1 In deployment

As part of the PCP, the following have been deployed:

- airport safety nets;
- automated assistance to controllers for surface movement planning and routing;
- departure manager (DMAN) synchronised with pre-departure sequencing;
- enhanced TMAs using RNP-based operations;
- arrival manager (AMAN) extended to en-route airspace;
- time-based separation for the final approach.

The following mature SESAR Solutions are proposed for deployment.

- Enhanced airport safety nets: this includes Runway Status Lights, a fully automatic system based on Advanced Surface Movement Guidance and Control System (A-SMGCS) surveillance and associated operational procedures; it increases safety at airports by preventing runway incursions.

- Airport safety nets vehicle: this addresses operational requirements and technical specifications to detect the risk of collision between a vehicle and an aircraft and to prevent infringement on restricted or closed areas. The vehicle driver is provided with an appropriate alert, either generated by an on-board system or uplinked from the airport safety net by the controller.

- Integrated surface management: this Solution provides enhanced guidance assistance to mobiles (aircraft and vehicles) based on automated operation of taxiway lights and stop bars in accordance with the airfield ground lighting (AGL) operational service. Additional guidance is provided to flight crew members and vehicle drivers based on coupling of taxi route management with AGL.

- Enhanced AMAN/DMAN integration: this Solution includes an improved AMAN for runways used for both arrivals and departures (referred to as 'mixed mode runways'), for which, in current operations, AMAN and DMAN sequences are not fully integrated. It includes the provision of an accurate, long-range runway sequencing and supports improved coordination between approach controllers and tower controllers.

4.2.6.2.2 In the development phase, in the pipeline towards deployment

SOLUTIONS APPROACHING MATURITY

- Efficient aircraft separation during take-off and final approach: this deployment scenario addresses solutions aimed at optimising wake turbulence separation minima for arrivals and departures, to increase airport runway throughput by exploiting wake separation reductions based on weather, static aircraft characteristics, ATCO separation delivery

support tools, wake risk monitoring and awareness functions (ground and airborne), wake vortex decay enhancing devices and minimum pair-wise separations based on required surveillance performance.

- Enhanced arrival procedures: these make use of satellite navigation and augmentation capabilities such as GBAS and SBAS to enhance landing capabilities and to facilitate advanced arrival procedures (e.g. glide slope increase, displaced runway threshold).

- Enhanced visual operations: these will result from the use of enhanced vision systems (EVS) and synthetic vision systems (SVS), which will enable more efficient taxi and landing operations in low-visibility conditions to improve access to secondary airports.

- Traffic optimisation on single- and multiple-runway airports: this will involve the provision of tower and approach controllers with system support to optimise runway operations' arrival and/or departure spacing and make optimal use of minimum separations, runway occupancy, runway capacity and airport capacity.

- Traffic alerts for pilots for airport operations: this refers to enhancing on-board systems for the detection of potential and actual risk of collisions with other traffic during runway and taxiway operations. In all cases, the flight crew will be provided with appropriate alerts.

KEY R&D ACTIVITIES

- Dynamic extended TMAs for advanced CCO/CDO and improved arrival and departure operations: the objective is to improve descent and climb profiles in busy airspace, as well as the horizontal flight efficiency of arrivals and departures, while ensuring traffic synchronisation, short-term DCB and separation. This activity has a very broad scope, which includes advances in airspace design, development of ground tools, and development of ATC and airborne procedures.

- Digital evolution of integrated surface management: this covers the development (e.g. using new algorithms, AI/expert systems) of procedures and the required system support for improved surface traffic management, including the extension of the A-SMGCS routing functions and the integration of inputs from airport DCB processes. This Solution will also include the provision of guidance assistance to both pilots and vehicle drivers using AGL, consolidation of related procedures, exchange of information between ATC and vehicles/aircrafts using airport datalink services, and other means of guidance.

- Evolution of separation minima for increased runway throughput: this activity aims to refine and consolidate static pair-wise separation matrices and weather-dependent separation minima for successive arrivals, successive departures and between arrivals and departures. It also aims to develop and validate the 'land behind without runway vacated' concept.

- Next generation AMAN for a 4D environment: this aims to extend the arrival planning horizon, and to incorporate increasingly complex and high-density environments in which en-route sectors serve more than one airport or more than one TMA, using advanced ground support tools and automation, including with regard to airspace constraints (speed and level restrictions, wind and temperature information). The solution also involves looking at highly integrated airports within the wider context of balancing demand and capacity across the network, and in relation to sharing data between systems.

- Advanced geometric GNSS-based procedures in TMAs: this solution validates the use of GNSS geometric guidance from the initial approach fix or earlier, facilitating a wider variety of curved approaches to a single runway. It also addresses curved departure routes that turn shortly after take-off in order to avoid noise-sensitive areas, approach routes or missed approach routes. For airports where there is a dependency

between departure and arrival runways, flexible and customised departure routes may be possible, thus allowing for an increase in capacity.

4.2.7 Fully dynamic and optimised airspace

While airspace in itself is seamless, it is traditionally partitioned into sectors, organised and managed at state level by the national ANSP according to expected traffic demand and airspace availability with, in some cases, agreements to address design and procedures at the boundaries with other states and FIRs. This local optimisation quickly reaches its limits and is inadequate to address crucial European network issues and in particular the emerging capacity crunch, which will become gradually unacceptable in the absence of ambitious and structural initiatives (see Chapters 2 and 3). Furthermore, there is continuous variation, in time and in space, in traffic density and complexity. There is therefore a strong need for a move towards truly flexible organisation and management of airspace structures. A real, network-centric optimisation, flexible and dynamic, will successfully handle the full trajectories of the flights and the major flows across Europe and will bring sufficient capacity when and where needed. An optimised airspace will ensure vertical and horizontal interconnectivity along with alignment of ATC sectors with traffic flows to support adaptable sector configurations. Airspace structures will allow efficient handling of ad hoc and dynamic situations, in which civil-military coordination will be optimal and free routes are expected to bring benefits.

4.2.7.1 Description of the essential operational change

This EOC includes further steps towards TBO by enhancing free-route airspace (FRA) processes and system support. It will needs to cover large-scale cross-border FRA. There is a need to ensure a smooth transition between FRA and highly structured airspace based on dynamic airspace configuration (DAC) principles. There is also a need for more dynamic, accurate and precise information on constraints, to allow the extension of FRA and the accommodation of different business trajectories.

FRA will be designed to minimise changes to trajectories and to achieve an optimum outcome for all stakeholders. In that respect, FRA will allow user-preferred routing, supported by collaborative decision-making processes; the Network Manager will play a central role in facilitating the coordination of stakeholders through its network management functions.

The first step will be the application of cross-border sectorisation, followed by implementation of DAC, to facilitate optimal use of airspace and reduce ATFCM delay. A fundamental change that needs to be delivered is that, among as many states as possible, an agreement needs to be reached on organising their mutual airspace into sectors, based on traffic demand (including military airspace needs) and irrespective of national boundaries. In addition, the states need to agree on partitioning the joint airspace for allocation of responsibility for ANS to qualified providers.

The dynamic airspace concept delivers an optimised and coordinated organisation of airspace activations and reservations, able to support optimised traffic flows in a free-route environment, as well as other uses of airspace (e.g. military). In essence, the main change is to move from ASM collaborative processes to ASM reconciled with ATC and ATFCM into a fully integrated ASM, ATC, ATFCM and collaborative decision-making layered process, resulting in fully dynamic airspace configurations (i.e. a higher level of modularity and flexibility up to the execution phase), supported by automated tools and also functioning as an enabler of integrated capacity management processes. The full integration of ASM, ATC and ATFCM processes within the DAC concept will contribute to the cost-efficient delivery of higher network performance through closer interaction between ATM operating phases, with consolidated and harmonised solutions integrated into the planning and execution phases at local, subregional and regional levels. The dynamic airspace will also require the development of new ATS working methods supported by automation and new tools.

4.2.7.2 Related SESAR deployment and development activities

4.2.7.2.1 In deployment

As part of the PCP, the following have been deployed:

- free route;
- Airspace management and advanced flexible use of airspace.

Supplementing the operational and technical requirements outlined in the PCP Regulation, the current deployment of free route has included implementation below FL310, as well as cross-border FRA in a substantial number of states, according to ANSPs.

4.2.7.2.2 In the development phase, in the pipeline towards deployment

SOLUTIONS APPROACHING MATURITY

- High-productivity controller team organisation: this relates to the extension of sector team operations beyond team structures consisting of one planning ATCO and two tactical ATCOs in E-TMA, in order to optimise flight profiles, minimise delays and improve ANSP cost efficiencies, while taking into account uncertainty in the trajectory.

KEY R&D ACTIVITIES

- Flight-centric ATC and improved distribution of separation responsibility in ATC: this activity relates to a concept involving assigning aircraft to ATCOs without reference to geographical sector, and having the aircraft controlled by that same ATCO across two or more geographical sectors. It requires flight-centric specific allocation, visualisation (traffic filtering), coordination tools (e.g. in the event of a conflict, to establish which controller is responsible for its resolution) and, for high traffic densities, advanced conflict detection and resolution (CD&R) tools (that are not flight-centric specific). In addition, it covers the concept of collaborative control with planned boundaries, in which sectors are retained as they are today, with aircraft being assigned to a sector according to its geographical location. The boundaries between sectors have planned coordination conditions, as in current operations, but with some additional flexibility by allowing controllers to issue clearances without prior coordination to aircraft in a different sector.

- Dynamic airspace configuration: the objective is to improve the use of airspace capacity for both civil and military users by increasing the granularity and the flexibility of airspace configuration and management within and across ANSPs' areas of responsibilities. This will result in the integration of concepts and procedures to allow flexible sectors that can be dynamically modified according to demand. This includes potential implications for ATCO licences, international boundaries, and potentially interoperability and air-ground multi-datalink communication capabilities.

- Mission trajectory management with integrated dynamic mobile areas type 1 and type 2: the objective is to improve the use of airspace capacity and the efficiency of ASM and to increase flexibility in civil-military coordination, for both civil and military users, through increasing levels of automation. Improvements include the connection of mission trajectory management with booking of airspace reservation (in the context of this solution, dynamic mobile areas type 1 and type 2), for which the WOC will be the key actor. Coordination between the WOC and the regional NM is a key element of this activity.

4.2.8 Trajectory-based operations

Historically, and with very few exceptions, ANS are provided at national level, with each national provider maintaining its own partial data of the flight and the context in which it is operated. This is highly limiting when the aim is to deliver the capacity needed and address the challenge of traffic growth while securing a safe, cost-efficient and environmentally optimised trajectory for the whole flight. In order to address

this challenge, duly taking account of future military airspace needs, controllers, pilots and advanced system functions will all need to share the same information about flights and use automated tools to assist in detecting, analysing and resolving potential conflicts, as well as in monitoring adherence to agreed and optimised trajectories.

4.2.8.1 Description of the essential operational change

TBO is an overarching SESAR concept, based on a wide range of solutions that, when combined, help achieve the envisaged paradigm change. A large number of solutions supporting the other EOCs are also contributing to TBO. In the following subsections, only the solutions that are specifically related to TBO are listed. It should be noted that the scope of TBO is much larger than the sum of the solutions listed below.

A trajectory is created and agreed for each flight representing the business needs of the airspace user and integrating ATM and airport constraints. This is the reference trajectory that the airspace user agrees to fly and that ANSPs and airports agree to facilitate. The integration of trajectory management processes into the planning and execution phases will involve the management, negotiation and sharing of the shared business trajectory (SBT) as well as the management, updating, revision and sharing of the reference business trajectory (RBT) and finally the transition from the SBT to the RBT.

This process will initially be deployed through an extended flight plan (eFPL), based on the ICAO tool Flight and Flow — Information for a Collaborative Environment (FF-ICE), to be prepared during the planning phase (before departure). This will progressively evolve to eFPL phase 2, which will encompass flight planning exchanges in the execution phase. This change will also involve ATC updates to SBTs/RBTs during the execution phase. Furthermore, during execution of the RBT, advanced separation modes (relying on new surveillance enablers such as ADS-B IN/OUT) and new safety nets will be put in place (relying on enhanced systems such as ACAS Xa).

With regard to mission trajectory, the first step is to improve the operational air traffic (OAT) flight plan. The improved OAT flight plan and corresponding process will accommodate individual military airspace user needs and priorities, benefitting ATM system outcomes and performance for all stakeholders. The EOC also includes some legacy deployments (ground-based and airborne safety nets) that are already validated concepts but have been included as they will facilitate trajectory execution for specific low-capability aircraft or in fallback procedures.

4.2.8.1.1 In deployment

As part of the PCP, the following has been deployed:

- initial trajectory information sharing (i4D operations).

The following mature SESAR Solution is proposed for deployment:

- Enhanced safety nets: this deployment scenario includes improvements associated with short-term conflict alert (STCA), a ground-based system designed and deployed as a safety net to prevent collisions in both en-route and TMA environments. Improving on existing STCA technology, the enhanced algorithms for STCA support controllers in identifying possible conflicts between aircraft, ensuring earlier warnings and lower rates of false and nuisance alerts. The system also makes use of downlinked aircraft parameters, available through mode S enhanced surveillance.

4.2.8.1.2 In the development phase, in the pipeline towards deployment

SOLUTIONS APPROACHING MATURITY

- eFPL supporting SBT transition to RBT: this solution will look at the distribution of eFPL information to ATC systems, and the possible improvements that could be made to the alignment of AU and NM trajectories, especially in relation to the

use of precision trajectory clearances and standard instrument departure / standard arrival route allocation.

KEY R&D ACTIVITIES

- Improved ground trajectory predictions enabling future automation tools: this activity focuses on the operational validation of improved CD&R tools. The main goal is to increase the quality of separation management services, reducing controller workload and separation buffers, and facilitating new ways of organising controller teams. The foundation is the improvement of the ground trajectory predictor (EPP data beyond weight and CAS, known MET data or new MET data, capabilities, etc.).

- RBT revision supported by datalink and increased automation: this aims to support a continuous increase in the amount and the usefulness of information shared between air and ground and in the level of automation support to controllers and pilots, for example through moves towards the automatic uplink of clearances with or without previous controller validation and towards increased use of auto-loading to the flight management system of uplinked clearances, as well as increased use of managed/automatic mode by the flight crew.

- Enhanced integration of AU trajectory definitions and network management processes: the objective is to reduce the impact of ATM planning on airspace users' costs of operations, by providing them with better access to ATM resource management and enabling them to cope better with ATM constraints. This will improve airspace users' flight planning and network management through improved FOC participation in the ATM network collaborative processes in the context of FF-ICE and its potential evolution.

- Improved vertical profiles through enhanced vertical clearances: the objective is to develop automation support for ATCOs to issue vertical constraints that help achieve more efficient flight profiles while ensuring separation provision. In the first step, for flights still in climb, enhanced predictions of vertical profile data are presented to ATCOs to facilitate decision-making. In a second, more advanced step, the ATC system will generate proposals for conflict-free clearances that take anticipated aircraft performance into account, and which can be uplinked to the flight crews by ATCOs.

4.2.9 Multimodal mobility and integration of all airspace users

Citizens increasingly expect a seamless mobility experience, and that their passenger experience will be smooth, safe and cost-efficient, with minimum delays, transfers and hassle. Implementing the multimodal mobility concept means that

passengers will not need to worry about selecting the most appropriate means of travelling. Through this concept, aviation and air transport will support a safe, efficient and green travel experience and promote use of the most appropriate means of transport. In this way, aviation will play its part in the global greening of transport and address the issues of congestion, delays and suboptimal passenger experience.

In addition, civil and military airspace users, stakeholders and state authorities (both civil and military) are recognising new business and mission opportunities enabled by the latest airborne vehicle technologies, in particular various types of drones and very high-altitude vehicles. These new opportunities have the potential to bring significant value to European society, in terms of industrial leadership, economic opportunities and passenger experience. These opportunities will be an integral part of the evolution of ATM towards fully integrated ATM in which all types of aerial operations are performed safely and efficiently.

4.2.9.1 Description of the essential operational change

Mobility as a service will take intermodality to the next level, connecting numerous modes of transport, for people and goods, in seamless door-to-door services. At any moment in time, there will be more, and more diverse, aircraft in the European skies than ever before, and drones (civil and military) will be completely and seamlessly integrated into all environments and classes of airspace, operating safely and efficiently alongside manned aircraft. Various modes of transport, such as car, train, helicopter, drone and aircraft, for different segments of a trip will be seamlessly combined. The integration of RPAS, rotorcraft, and business and general aviation operations through IFR procedures using performance-based CNS infrastructure in the airspace surrounding airports, as well as in TMAs, is a priority. Equal access for all airspace users to the airspace will broaden the options for achieving door-to-door mobility. A coherent, multimodal regulatory framework may be needed to support this objective, including new ATC methods and a review and adaptation of ATS. ATM as a whole needs be flexible enough to accommodate new developments associated with intermodal transportation.

4.2.9.2 Related SESAR deployment and development activities

4.2.9.2.1 In deployment

The following mature SESAR Solution is proposed for deployment.

- Optimised low-level IFR routes for rotorcraft: currently, GNSS technology enhanced by SBAS systems (without ground infrastructure), which provide the required integrity for GNSS signals, identifies the availability of specific IFR routes, with improved accuracy, reliability and accessibility, to enable rotorcraft operators to access controlled airspace. Furthermore, the ICAO PBN concept, owing to the development of the RNP1/RNP0.3 navigation applications, makes a wide range of benefits available, with the aim of enhancing rotorcraft operations and integrating them into the future ATM system.

4.2.9.2.2 In the development phase, in the pipeline towards deployment

SOLUTIONS APPROACHING MATURITY

- Independent rotorcraft operations at airports: this solution involves the use of rotorcraft-specific and SBAS-based point-in-space (PinS) approach procedures, which aim to improve access to secondary airports in low-visibility conditions.

- Enhanced rotorcraft and general aviation operations in the TMA: this solution further develops the simultaneous non-interfering concept of operations to allow rotorcraft and general aviation to operate to and from airports without conflicting with fixed-wing traffic or requiring runway slots.

KEY R&D ACTIVITIES

- Collision avoidance for IFR RPAS: this activity will involve developing and operationally validating a DAA system for IFR RPAS, which consists of two functions: 'collision avoidance' and 'remain well clear'. These enable the remote pilot to contribute to ensuring that safety requirements are met by preventing collisions should normal separation provision fail. The 'remain well clear' function is designed to increase the remote pilot's situational awareness.

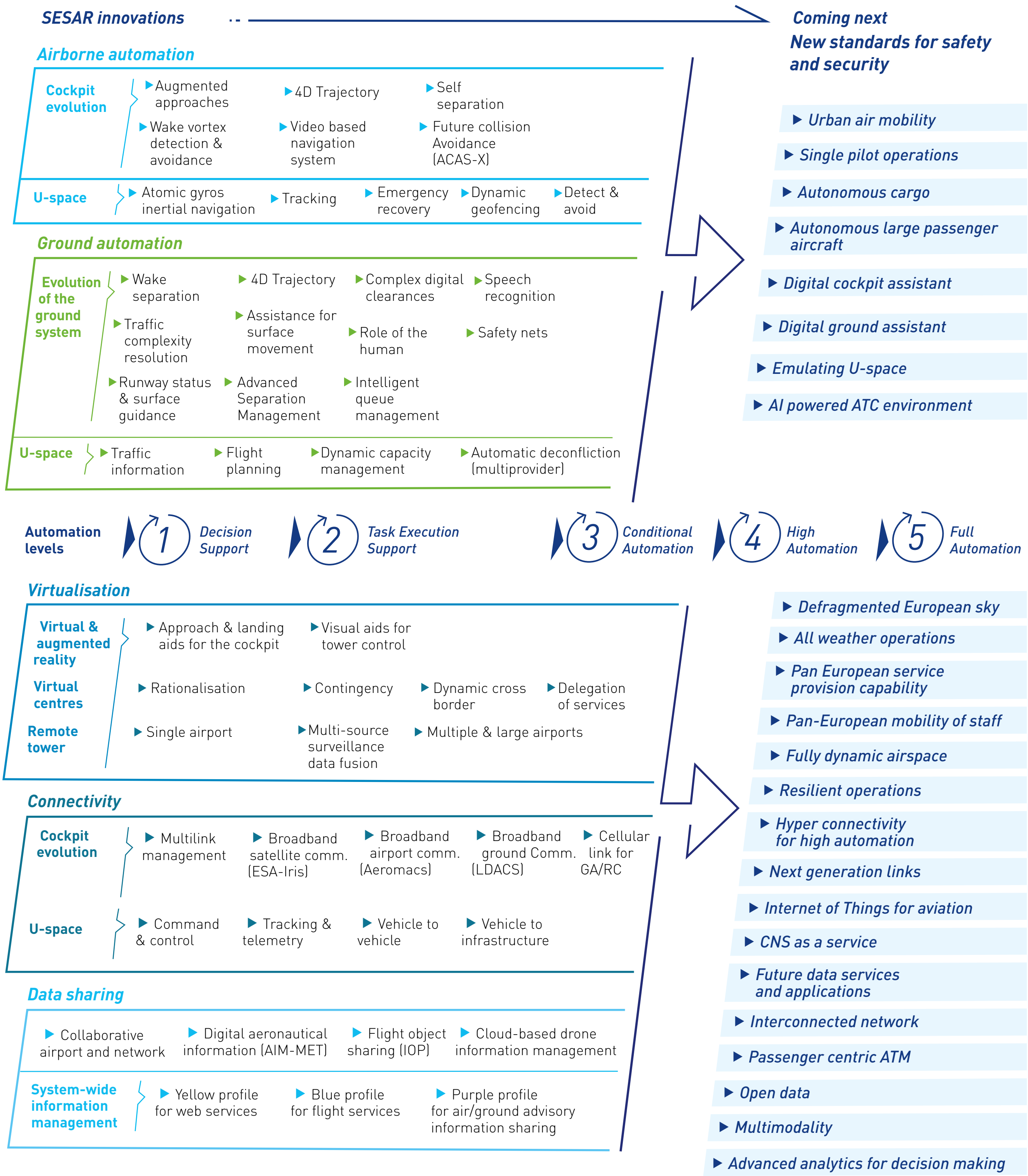
- IFR RPAS accommodation in airspace classes A to C: the aim is to accommodate IFR RPAS in non-segregated airspace in the short term, in accordance with the drone roadmap in the Master Plan. The idea is to enable IFR RPAS operating from dedicated airfields to routinely operate in airspace classes A to C as general air traffic without a chase plane escort. Changes to ATC procedures, adaptations to flight planning processes, contingency measures, etc., are included in the development activity.

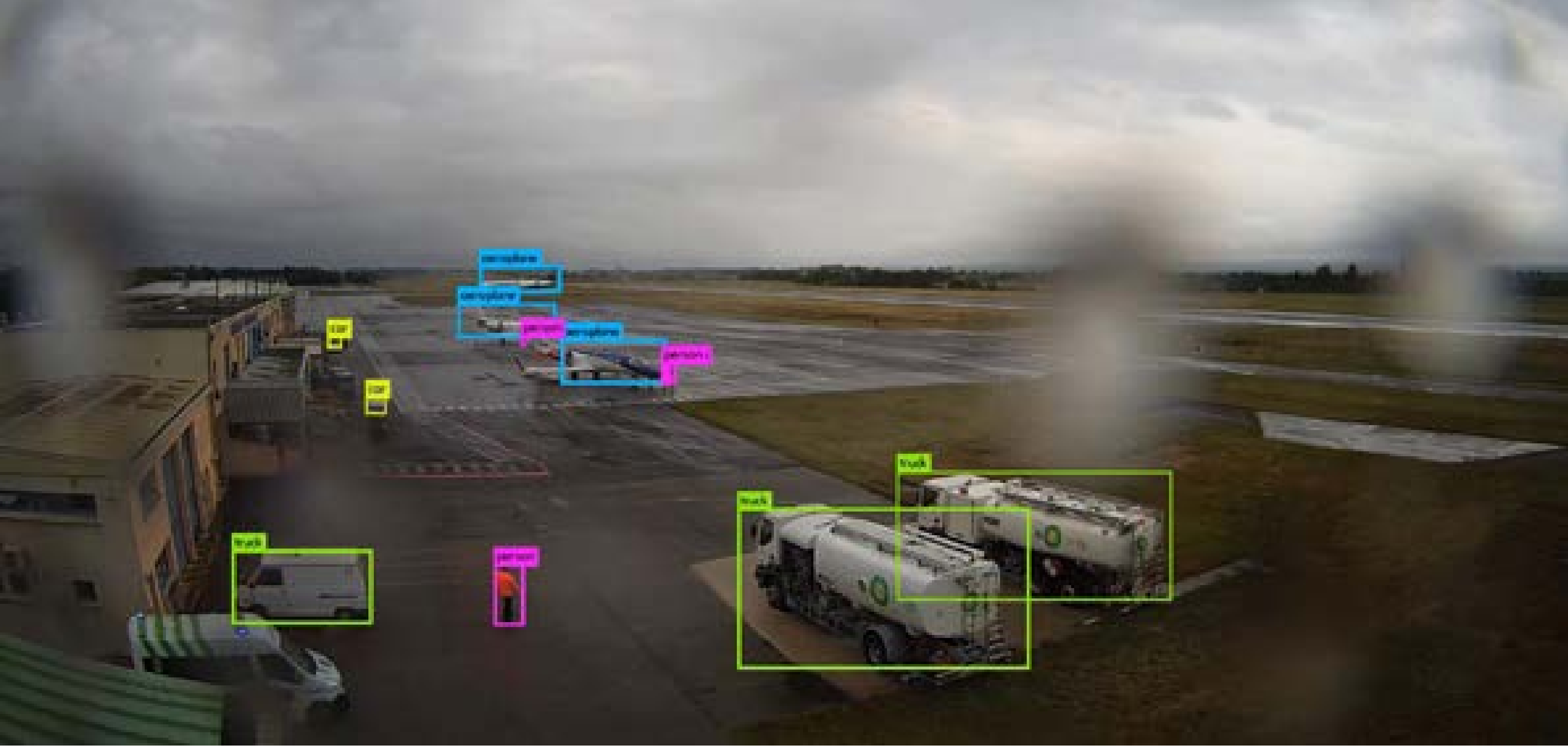
- IFR RPAS integration into airspace classes A to C: the aim is to provide the technical capabilities and procedural means to allow IFR RPAS to comply with ATC instructions, and to develop new procedures and tools to allow ATC to handle IFR RPAS in a cooperative environment in full integration with manned aviation. This will also involve developing and validating an operational DAA system for IFR RPAS.

4.3 DELIVERING THE DIGITAL EUROPEAN SKY (PHASE D)

Thanks to the innovation pipeline, SESAR is making progress towards higher-performing aviation for Europe. The ATM solutions resulting from the SESAR 2020 R&D programme are the principal means of delivering the improvements sought, at least until the end of phase C. Nevertheless, further innovations, many initiated outside the ATM industry, will be

FIGURE 14. WHAT IS COMING NEXT?





needed to achieve the digital European sky targeted by the vision.

The digital transformation of ATM will bring the necessary leap forward in technology and operational capabilities that is required to meet the performance challenges described in Chapter 3. Future solutions will have to be developed to enable the deployment of a resilient, scalable, safe and cybersecure ATM system. Most of these solutions are not yet ready and will have to be researched while, in parallel, new operational concepts and services are defined, making full use of these digital solutions to improve system performance. Therefore, investment decisions looking beyond SESAR 2020 will have to be taken rapidly to ensure that these additional solutions are ready for deployment in due time.

It is anticipated that the following challenges and opportunities will have to be addressed in order to prepare the ground for the digital European sky targeted by phase D of the SESAR rollout.

• Future operations

As traffic continues to increase and grow in complexity, the pressure for better ATM performance will continue to grow. All operational actors (airlines, airports, networks, ANSPs, the military, etc.) will continue to seek new operational solutions that will help in dealing with the day-to-day challenges. The aviation community will require fully scalable services supported by a digital ecosystem minimising the environmental footprint. The requirements for highly resilient and efficient airport operations, passenger-centricity and multimodality will be growing concerns. In this context, research should deliver future operational solutions that will take advantage of modern techniques to address ATM performance.

Themes: future ATM network services, future ATS, future airport operations, future aviation infrastructure.

• Air/ground integration and autonomy

The progress made in the fields of machine learning and AI has opened the door to a myriad of applications in ATM. Many tasks in aviation that today can be performed only by humans can be automated in future, enabling an increase in the safety and scalability of the air traffic system. AI-powered systems are expected to be integrated into the cockpit and into systems on the ground, which will open the door to air-ground machine-to-machine communication for trajectory management and much more. Aerial vehicles will evolve with the emergence of new trends, such as SPO, and new vehicles types, such as cargo and passenger drones. The electrification trend will continue to change aircraft characteristics and operations. U-space unmanned traffic management is expected to use unprecedented levels of automation, which are likely to start making their way into traditional aviation. Research should explore if and in what ways automation can be used to deliver substantial and verifiable performance benefits while fully addressing safety concerns.

Themes: urban air mobility, SPO, autonomous cargo, autonomous large passenger aircraft, automation Level 3 and beyond for ground systems, U-space U3 and U4, RPAS IFR and visual flight rules classes A-G, ATM-U-space convergence.

- **Virtualisation serving scalability and resilience**

Increased automation and virtualisation hold the greatest promise for effectively balancing supply (of ATC) and demand (for flights) while ensuring higher levels of resilience. With services delivered irrespective of physical infrastructure or geographical location, the defragmentation of European skies can be realised through virtualisation. Airspace capacity can be offered on demand through horizontal collaboration between ANSPs. The digital European sky will allow more efficient and flexible use of resources, substantially improving safety and the cost efficiency of service provision and relieving congested airspace. Augmented and virtual reality systems will also allow the delivery of geographically decoupled services. Ultimately, the virtualisation of ATC services will enable the creation of new business models and foster competition in the sector.

Themes: all-weather operations, infrastructure as a service, scalability and resilience.

- **Hyper-connectivity and machine-to-machine applications**

The digital transformation of aviation will need to be backed up by an increase in connectivity capacity, speed and reliability. Different technologies and standards, such as 5G and satellite-based solutions will allow this to happen. The need to be always connected will become the new standard, both for safety-critical and non-safety-critical applications, including passenger experience. R&D is needed to develop a future concept for air-ground digital communications that will make it possible to overcome the current VHF limitations and enable growth. In addition, specific R&D may be undertaken to support the simultaneous use of multiple alternative means of data and voice communication between the flight deck and ATC, including using open links such as 5G secure connectivity. The internet of things for aviation could be implemented. Machine-to-machine communication will open up possibilities for real-time and automatic decision-making to improve efficiency in various sectors of aviation.

Themes: next generation links, networks and applications.

- **Data sharing and data services**

In the future, data sharing through interoperable platforms and open data policies will allow collaboration between various actors and the optimisation of services and process. The sharing of data will allow the improvement and creation of data-based services such as big data analytics. Aviation is already a sector that generates a huge number of data. However, with the emergence of open data trends, the full potential of big data analytics in aviation can be explored. Data from various sources such as flights, air traffic or airports aligned with powerful analytics will allow for improvements and efficiency gains in many operations, such as predictive maintenance, route optimisation and personalisation of customer offers. Ultimately, data services and information sharing will allow better-targeted decision-making by all stakeholders. New data-sharing standards and systems will allow new 'as a service' businesses to emerge, allowing the creation of more value for aviation.

Themes: future data services and applications for ATS, airport and network planning, passenger-centric ATM, open data.

- **New standards for safety and security**

The increase in the number of connected devices and common standards will result in increase in vulnerabilities and a higher possibility of cyberattacks. The need for new standards addressing safety and cybersecurity will emerge. It will also be necessary to further develop cybersecurity techniques for ATM, including the transfer to ATM of cybersecurity knowledge from other domains (e.g. system design principles, cryptography, blockchain, software-defined networking). Research should support the development of concepts enabling the level of cybersecurity to be maintained in an environment where threats are continuously evolving. An integrated operational and technical architectural approach will be required. Cybersecurity and safety considerations for systems powered by advanced digital technologies (e.g. AI, speech recognition) will have to be taken into account. Designing safety and cybersecurity provisions for highly automated systems will be a major challenge and will open up new avenues of research.

Themes: provisions for highly automated and autonomous air-ground systems, integrated safety and cybersecurity, the trust framework in hyper-connected and virtual networks, system and human performance.

4.4 LINK TO THE GLOBAL CONTEXT

4.4.1 The ICAO Global Air Navigation Plan

Together with the European institutions, SESAR has continuously and actively contributed to the development of the ICAO GANP and the aviation system block upgrades (ASBUs). Cooperative arrangements have been established with the United States and several other states and regions of the world at the level of agreeing common views regarding GANP-related developments and their implementation. The recent 3rd edition of the **Next Generation Air Transport System** report *NextGen —SESAR state of harmonisation*[48] explains the key interoperability and harmonisation areas contributing towards the implementation of the ICAO GANP.

In the development of the GANP for endorsement at the 40th ICAO General Assembly in 2019, the European input into the 13th ICAO Air Navigation Conference (ANC13) led to positive results in line with the recommendations made by the EU Member States' and ECAC states. The recommendations from ANC13 will guide the development of the GANP towards a

[48] NextGen – SESAR State of Harmonisation, 2018 https://www.sesarju.eu/newsroom/brochures-publications/state-harmonisation

new era for aviation, with new entrants and digital enabling capabilities emerging and allowing higher performance levels in global aviation. This plan will correspond to achieving phase C of the vision, as outlined in Chapter 2.

It was agreed that the GANP would now be structured similarly to the Master Plan. The content of the GANP is organised in four layers: the global strategic level, the global technical level, the national level and the regional level. This will enable stakeholders to access and use information at the level of detail relevant to their area of interest. The global strategic level sets the vision for global aviation, the performance ambitions and the conceptual roadmap. Together with an executive summary, this level is aimed at policymakers and the executive level of the stakeholders within the global aviation community. The global technical level addresses the expert level, providing detail on the application of improvements to operational environments based on performance needs. There will also be a GANP portal, similar to the Master Plan portal, where the aviation community can access information.

The GANP now has clear links with the ICAO Global Aviation Safety Plan, similar to those between the Master Plan and the European Aviation Safety Plan. The ICAO Global Aviation Security Plan will have similar links to the GANP, which is something that could be considered in relation to the Master Plan and a European security plan.

To ensure alignment and the required links to the Master Plan, the SJU has, together with the European Commission, EASA and Eurocontrol, actively supported the ICAO Secretariat through organised working groups in which all regions of the world have participated with industry organisations such as the International Air Transport Association, Airports Council International, the Civil Air Navigation Services Organisation, the International Coordinating Council of Aerospace Industries Associations, the International Federation of Air Traffic Controllers' Associations and the International Federation of Air Line Pilots' Associations. Active coordination is ongoing among the European members of panels and working groups under the Commission, and ECAC-chaired coordination groups.

It can now safely be said that the GANP aligns well both in vision, performance ambitions, structure and technical content with the Master Plan and SESAR Solutions. This ensures that the necessary ICAO provisions will be in place, allowing refinements to take place at European level to the benefit of SESAR strategies, planning and implementation.

4.4.2 Harmonisation with other major modernisation programmes

As a major ATM modernisation programme, SESAR shares responsibility for and interest in harmonisation as a means of ensuring safe, efficient and seamless global interoperability. It is also very well understood that harmonisation and interoperability mean not being completely identical but, rather, being harmonised and interoperable at the level of standards. SESAR, NextGen and other state and regional ATM modernisation programmes advocate a 'one size does not fit all' approach, as accepted by the ICAO with the aim of achieving the harmonisation necessary to:

- ensure flights/aircraft can operate seamlessly in all regions without requiring additional capabilities;
- ensure that common standards are available in a timely manner;
- optimise development and implementation costs through the sharing of efforts and results.

In recent years, we have seen a growing recognition of the SESAR brand and SESAR Solutions. This relates in part to the fact that European states and stakeholders have together continuously and consistently aligned the Master Plan and SESAR Solutions with the ICAO GANP and ASBUs (see Annex B), but it is also because deployments are now taking place, delivering operational performance benefits. Based on the credibility established globally through the Master Plan, there is increasing uptake outside Europe of SESAR Solutions and European SESAR partners' products and services. There are also now more specific requests from non-European states for collaboration relating to SESAR Solutions in several key areas, not least the new digital technologies and emergence of new entrants into the airspace.
The SJU aims to use its cooperative arrangements with other states and regions of the world as a platform for building cooperation on specific topics of mutual interest, in addition to ensuring alignment with the ICAO.

4.5 THE ROLE OF THE HUMAN

4.5.1 An integrated view of the ATM system

In ATM as in all industries, human capital is a critical and an integral element of the system. Changing demands on ATM require a radical increase in the dynamics of the system to secure its scalability (up and down) and resilience, ensuring that all air traffic is handled safely and efficiently, even under the highest traffic growth forecast or during stagnation or unexpected downturn. To achieve this goal, digitalisation and automation will play a central role. In this context, the role of the human and of human interface with machines — making optimal use of the strengths of humans and their capacity to control the tools, use the support provided by machines to manage situations, and quickly and safely react to the unexpected — will require careful consideration.

This will require attention to and the development of the role of the human, in parallel with ATM concepts and technological developments, throughout the Master Plan life cycle.

To support uniform human-system integration in the ATM system, the following will be key.

- A new work system ([49]) will emerge and new roles will be created to replace, supplement or modify current roles in the existing ATM system. Changes to the characteristics of the work system will have consequences, for example with regard to the ability to coordinate between system actors (be they human or machine actors), the timeliness of access to resources and the ability of the work system to adapt.
- Following a total system approach, the new work system must provide new tools to support continuous, system-wide awareness of the status of all critical processing, at all times, including during

([49]) A work system is a system in which human participants and/or machines jointly perform work (processes and activities) using information, technology and other resources to produce products/services.

degraded modes of operation or, for example, cyberattacks.

- New tools must enable humans to make effective decisions, including where collaborative, co-adaptive and joint intelligence modes of decision-making are used (in the controller working position, the cockpit, the air traffic safety electronics personnel (ATSEP) working position, etc.). In addition, these tools must support capacity for containing cyberattacks and technical failures, ensuring recovery and safety throughout the functional system. The joint work system will need to have explicit objectives that optimise performance and resilience.

- Achieving the SESAR ATM target concept, described in Section 4.1, will therefore require a different approach to defining the role of the human from that used in the past. It will be necessary to acknowledge and embrace the interdependence between the various actors in the loop, human and machine, working together in joint activity with shared processes built on an integrated design that optimises the collaboration of actors with a view to optimising system performance.

- The work system design will be based on a systems thinking approach, according to which optimised system performance stems from fully understanding task distribution and system dynamics. The design will explicitly incorporate requirements for human and machine actors enabling effective collaborative work across the entire system. The delivery of sustained system performance will also be supported by a design that provides sources of resilience.

- Change management, which is an indispensable component of the development, implementation and in-service life cycle of the SESAR ATM target concept, will be consistently undertaken. It is integral to the successful implementation of large and complex socio-technical systems, to ensure not only that preparation for transition to a new work system is embraced but also that sociological factors and the needs of all actors involved, including those who will influence and enable organisational change, are taken into account.

4.5.2 Changes to address

The following developments are anticipated within the work system:

- the gradual digitalisation of the ATM (see Chapter 2);

- in this context, the changing human role and the changing nature of work carried

out by human,, which will emerge from the implementation of the ATM target concept;

- new work relationships and dependencies, as the integrated nature of work evolves.

It is not yet possible to describe the full scope and scale of the changes in detail owing to changes in the human role as the work system itself evolves.

From the analyses performed on changes within the scope of SESAR, the following most critical challenges and assumptions with regard to the human role in ATM have been identified.

- Potential exists for redistribution of tasks and functions between existing system actors (between humans in the system, and between the human and the machine) and new, emerging roles.
- The traditional belief that the human will manage unexpected events unaided or unsupported is no longer viable.
- A new human-machine integrated approach will be utilised to deliver targeted performance in nominal and non-nominal conditions.
- In some cases, responsibilities traditionally attributed to human roles (pilots, ATCOs, ATSEP), including for system maintenance and supervision, will change. This may result in machine actors taking over a number of tasks, for instance where it is not possible for the human to perform any meaningful function.
- Assistance will be provided by new tools to enable human operators to address new challenges such as cybersecurity, new degraded modes or cascade failure effects due to the interdependence and tightly coupled relationship of interoperable ATM/ANS systems.
- The legal implications of human and machine actors sharing tasks, in terms of responsibilities and accountabilities, will be determined at every step-change towards the ATM target concept.
- The joint nature of a collaborative work system introduces new factors and behaviours that serve to add complexity and system variability, as each new function may involve differing combinations of human and system elements working together and interacting functionally.

- In particular, for cybersecurity, new tools will be needed to enable actors to distinguish, for all systems, between system failures and cyberattacks.

- Change management will remain an essential element of the critical path for successful implementation of the target concept. In keeping with the systems approach, the scale of collaborative activities will include a broad range of roles, actors and organisations at all levels.

- The skills and knowledge required of human actors — system wide — will be different, generally more managerial and complex, in future. Ongoing competence and capability will be achieved only through integrated continuation training.

- There will be a greater need for in-depth technical training for humans in ATM to address the higher level of complexity of SESAR systems and the need, during a transitional period, for workers to continue to maintain the ability to use legacy systems as long as they remain in operation.

- While change management will be used, social issues may still arise as a result of the redistribution of responsibilities and changes in the business models of ANSP operations within the European ATM system.

4.5.3 Approach to change management

Changes introduced during the SESAR development and deployment phases will require the successful transition of affected staff from current systems to new systems. In addition, human actors will be granted new responsibilities for achieving effective system performance and safety.

During the transition of legacy systems to SESAR-based systems, concurrent operations and the possibility of cascade failures in interconnected systems must be taken into account. New tools will be required to ensure total system awareness following the introduction of new ways of working and new system architectures. The transition from segregated ATM/ANS systems to a networked environment will require effective ways of managing the change.

To retain optimal levels of service, an adapted approach to operations, management and leadership will be required. This includes the participation and involvement of staff and management in an effective partnership.

Key enablers contributing to the success of SESAR development and deployment will remain the following.

- **Staff involvement.** The effective and active participation and involvement of the European civil and military aviation communities, including trade unions and professional staff organisations, within R&D activities and subsequent deployment activities will be required, to enable proactive identification of social and change management risks and opportunities, with regard to the common goal of improving the overall performance of the ATM system. The involvement of staff and staff representatives in validation activities and simulations (e.g. through the international validation team) will support this goal.

- **Social dialogue.** Social partners in the European Sectoral Social Dialogue Committee for Civil Aviation must ensure that all affected parties are appropriately represented and must take a proactive and supportive role in ensuring the successful implementation of the SESAR target concept, through stable participation structures and clearly defined mandates.

- **Training.** Consideration of the effort and costs associated with changes to the role of the human is crucial. This may include training staff, development training, technical training involving staff in simulations and procedure design, training infrastructure development, and 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 included in business cases related to SESAR deployment.

- **Change management.** Provisions will be made for 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.

A change management strategy across the extended ATM system is an essential prerequisite to fulfilling the ambitions of the Master Plan. A clear change management strategy and associated planning to initiate, implement, manage and steer effective and sustainable change and transition within all organisations should be established before SESAR deployment.

This will be supported by appropriate governance and management to ensure that personnel have reached the capability required for each role or function to be undertaken. Where new roles and capabilities are introduced, competence to undertake such roles with confidence will need to be proven and attained.

A strategic change plan — to include a clear statement of the objectives of change, timescales, resources, communication plans, a description of the contribution of staff (in deployment activities, with regard to the establishment of a social forum at European, national and company levels, etc.) and risks associated with the execution of the plan — is needed.

Building the momentum for change will involve taking into account the need for humans to develop effective working relationships with new actors and to develop new working methods. Change management will support and enable the transition through the step-changes of the numerous iterations of the delivery of the ATM target concept. This will include, but not be limited to, implementing a pattern of changes that will lead humans to feel that they are in control and able to navigate the changes in ways that do not compromise their safety or competence.

4.5.4 Gender equality in ATM

ATM in Europe used to be a rather male-dominated business, and it lags behind many other businesses when it comes to balancing gender participation at all organisational levels.

Not only is the share of women in most ATM organisations lower than that of men, women are in particular often underrepresented at higher management levels.

Most organisations today recognise the added value that gender equality and also ethnic and cultural diversity bring to organisations. While transforming the European ATM system over the years to come, as described in the Master Plan, all ATM organisations are strongly encouraged to achieve balanced gender participation at all levels of their organisations in line with the European initiative 'Women in Transport — EU Platform for Change' ([50]).

([50]) See also the EU 'Declaration on equal opportunities for women and men in the transport sector' (available at https://ec.europa.eu/transport/themes/social/women-transport-eu-platform-change_en).

4.6 CYBERSECURITY IN A SAFETY-ORIENTED INDUSTRY

The main objective of SESAR is to deliver a fully scalable system, fulfilling successfully the growing capacity needs while remaining even safer than today's system, striving to achieve the ambition of 'no ATM-related accident' (see Chapter 3). From a safety perspective, this means that all SESAR Solutions will be validated to deliver safety performances that, taken collectively, will make it possible to maintain or improve on the current high safety levels despite the increase in traffic.

The aviation system will evolve significantly in the future, with the application of new operational concepts, an increased use of commercial off-the-shelf products developed using open standards, increased sharing of data and networking of systems, and the introduction of new vehicles into controlled airspace. The next generation of systems resulting from the digitalisation of aviation will apply emerging technologies (e.g. AI ([51]), data analytics, new security technologies, etc.), and may introduce new threat vectors, particularly in the area of cybersecurity, the exploitation of which could result in undesirable impacts on safety of operations, capacity, delays, cost efficiency and the environment.

The Advisory Council for Aviation Research and Innovation in Europe (ACARE) Strategic Research and Innovation Agenda supports the realisation of the goals of Flightpath 2050 (52). Safety and security are addressed by five common threads that are equally relevant in the context of the Master Plan:

- **Collaborate** for security: a framework must be in place for system-wide security governance, addressing policy, regulation and oversight, and the application of appropriate security management systems.
- **Engage personnel and society:** the means to develop a security culture must be established and implemented across the aviation industry.

([51]) Artificial intelligence, machine learning, deep learning and data analytics are all concepts in a scientific domain that is rapidly evolving. There is no unanimously agreed taxonomy on these terms. Therefore, the term 'AI' is meant here in the broadest sense of the word, and includes data analytics, machine learning and deep learning.

([52]) European Commission, *Flightpath 2050 — Europe's vision for aviation: report of the High Level Group on Aviation Research, Publications Office of the European Union, Luxembourg,2011* (https://ec.europa.eu/transport/sites/transport/files/modes/air/doc/flightpath2050.pdf).

- **Security intelligence:** this will be required to provide the information necessary to effectively identify current threats and vulnerabilities, and predict and prepare for those emerging in the future.

- **Operational security:** capabilities in incident management must be developed to deliver the means of detecting security incidents in real time, and responding and recovering rapidly.

- **Design, manufacture and certify for security:** this will be important to ensure that security is addressed in all phases of the life cycle, including design, manufacture, deployment, operations and decommissioning, supported by the provision of appropriate methods, tools, guidance material and standards.

Several past and ongoing research projects address aspects of the abovementioned issues. There are, however, a number of key areas that require particular security attention in the short term, with the application areas of CNS systems — where security has traditionally not been designed in, where protocols are used that are susceptible to eavesdropping, jamming and flooding, and where authentication or integrity checks are weak or absent, and drones, which may introduce new threats to aircraft, airports and third parties — being of particular interest.

OPTICS2 workshops have provided additional insights into research priorities, including the need to:

- develop capabilities in secure information acquisition, storage and dissemination;

- develop system architectures that support the development of secure, resilient systems, capable of rapid adaptation to novel attack vectors;

- develop modelling and simulation tools capable of demonstrating the compliance of a system with security requirements;

- apply intelligent systems to a variety of areas of aviation security (the application of AI to user-behaviour analytics, network surveillance or incident forensics, for example, could provide a system with the capability to react autonomously to breaches, adaptively delaying or neutralising ongoing or developing attacks);

- carry out research into the safety assessment and certification of safety-critical systems that incorporate technology based on AI.

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 to or have a profile developed for ATM.

DEPLOYMENT VIEW

This chapter describes how and when the technology that is successfully rolled out from SESAR should be deployed. Section 5.1 provides a high-level holistic view for the entire SESAR project, while Sections 5.2 to 5.5 provide further details for changes that are in the pipeline towards deployment.

5.1 HOW AND WHEN THE SESAR VISION SHOULD BE DEPLOYED

5.1.1 Status of SESAR Solutions

The achievement of the SESAR vision outlined in the Master Plan requires the development and subsequent deployment of SESAR Solutions. These solutions fall into three categories.

1. **Delivered** ([53]): solutions successfully rolled out from R&D with demonstrated benefits and transferred to deployment. These mainly cover phases A and B of the vision for the time being.

2. **In development** ([54]): solutions that are currently under development within the SESAR programme and are expected to reach readiness for industrialisation within the lifetime of the current SESAR 2020 programme. These will cover the remaining elements of phase B and allow the delivery of the Master Plan vision up to phase C. These solutions will be transferred to the deployment phase once maturity is reached.

3. **Estimated future R&D** ([55]): solutions that are needed to achieve the digital European sky (phase D) and that are currently being further explored.

FIGURE 15 ([56]) shows the shares of SESAR Solutions across these three categories. It also shows the percentage of solutions that have been already transferred to deployment and depicts deployment status as described in the Master Plan Level 3.

The deployment status (57) of delivered SESAR Solutions is described as follows.

- The adoption of an implementation objective in the Master Plan Level 3 yearly plan implies that a deployment decision has been taken.

- In the absence of an implementation objective in the Master Plan Level 3, it is assumed that no deployment decision

([53]) SESAR Solutions catalogue, 3rd edition, 2019 (available from the SJU website https://www.sesarju.eu/solutionscatalogue).

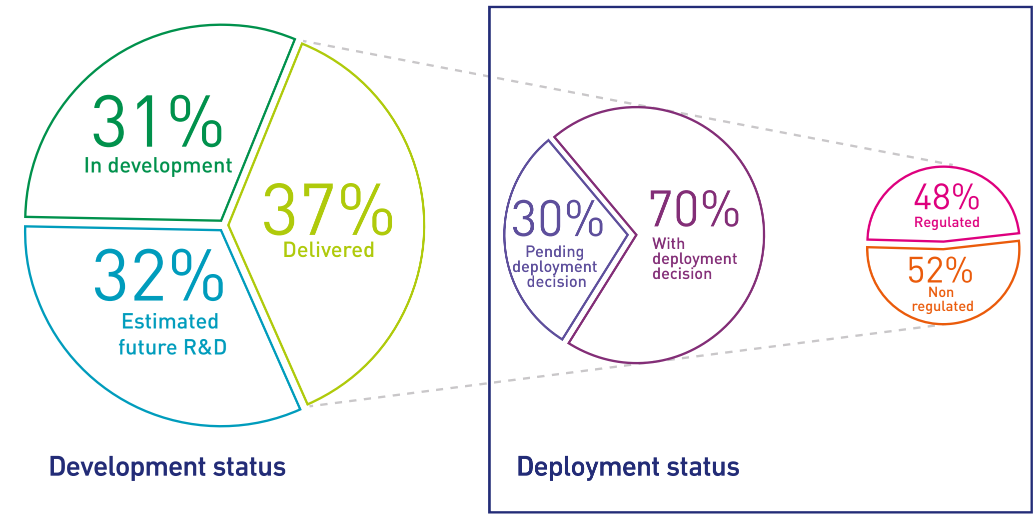
([54]) SJU single programming document 2019-2021, https://www.sesarju.eu/sites/default/files/documents/adb/2019/SJU%20Single%20Programming%20Document%202019-2021.pdf

([55]) Based on research needs identified in Section 4.3 above.

([56]) SJU analysis, based on expected Master Plan Levels 1, 2 and 3 planning data by the end of 2019. The analysis took into account reporting data concerning, for example, the state of implementation of the PCP.

([57]) Draft Master Plan Level 3, 2019 edition (www.ATMMasterPlan.eu)

FIGURE 15. STATUS OF SESAR SOLUTIONS



has been taken yet and, therefore, the deployment of the associated solution is described as 'pending deployment decision'.

Finally, for the subset of SESAR Solutions for which a deployment decision has been taken, **FIGURE 15** also presents the shares of those that are linked to functionalities regulated (through the pilot common project) against those that are non-regulated.

SUCCESS STORIES

Read about success stories of the development and implementation of SESAR Solutions at: https://www.sesarju.eu/in-practice

5.1.2 Key milestones for SESAR deployment

Although SESAR has already contributed to shortening the innovation cycle in ATM from 30 years to approximately 15-20 years, achieving the SESAR vision by 2040 will be challenging in the present context and using the present ways of working. In order to complete this transformation, it will therefore be essential to move towards new ways of working within SESAR and a regulatory framework that encourages innovation to enable a further shortening of the innovation cycle to 5-10 years. With these changes and strong collective commitment and motivation, it is likely that the transformation can be delivered by 2040 with significant positive consequences for EU growth, EU citizens, and the attractiveness and sustainability of the aviation sector at large.

Enabling this accelerated path requires key decisions that will shape the execution of the SESAR project in the 2020+ time frame to be taken very rapidly; these decisions will help in achieving the following key intermediate milestones leading up to 2040.

- By 2025, in addition to the already planned rollout of the first SESAR results (e.g. through the PCP), new programmes on airspace reconfiguration and operational excellence have delivered quick wins. Regulation has evolved to support the transition ahead, and drone accommodation, including initial U-space services implementation, is complete across Europe.

- By 2030, the implementation of the next generation of SESAR technologies is complete, with the rollout of virtualisation techniques and DAC, supported by the gradual introduction of higher levels of automation support. The new architecture enables resources (including data) to be shared across the network, supporting flexible and seamless civil-military coordination and allowing for more scalable and resilient service delivery to all airspace users. Advanced

U-space services are operational across Europe.

- By 2035, the full defragmentation of European skies through virtualisation is complete. The network operates at its optimum capability, having fully evolved from a system based on punctuality to a system based on predictability, and can safely and effectively accommodate 16 million flights (+50 % compared with 2017). Drones, along with all aerial vehicles, are efficiently integrated into both controlled and uncontrolled airspace.

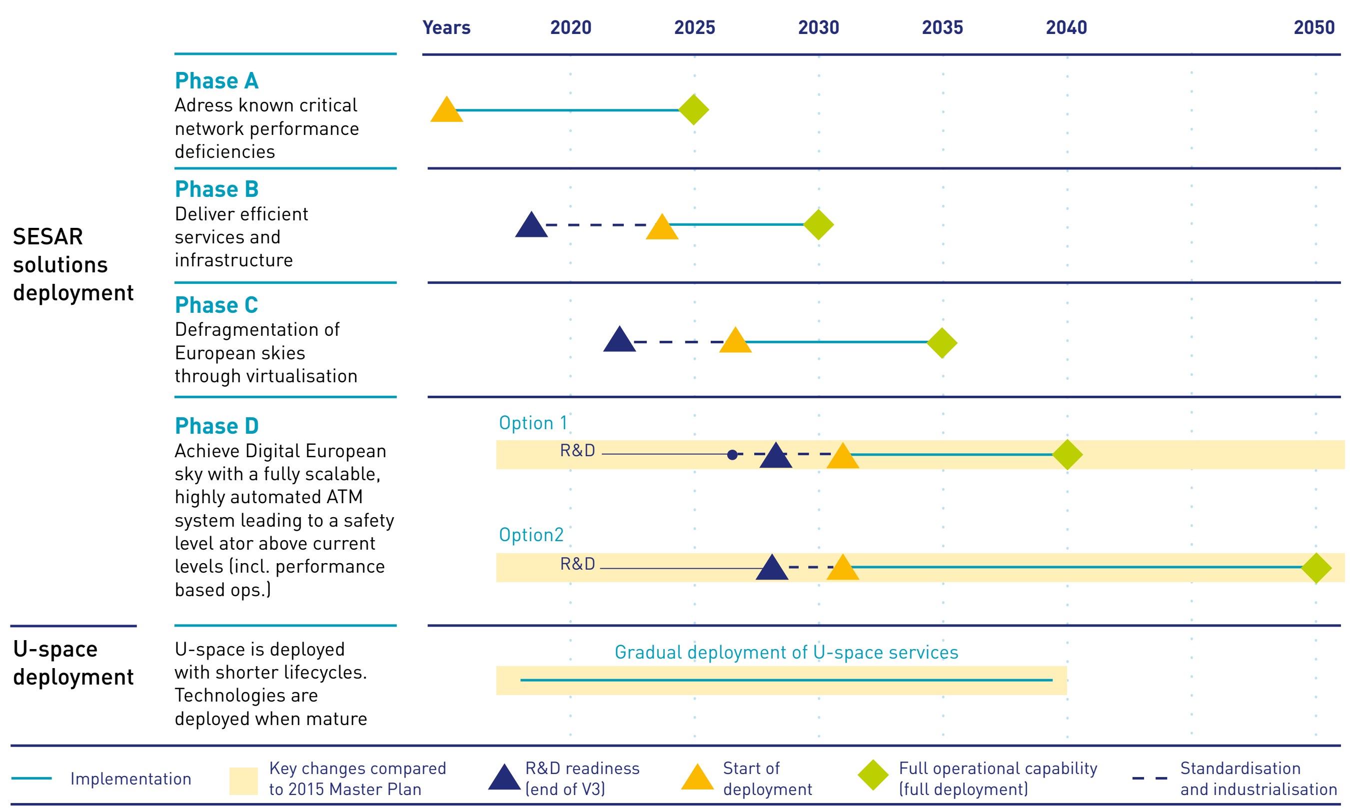
Two main rollout options have been identified, which may also take the form of a number of intermediate scenarios; depending on the extent to which the ATM community joins forces and changes working methods, it should be possible to reach the implementation of the full SESAR vision by 2040 (option 1) or 2050 (option 2).

FIGURE 16 shows the various milestones for SESAR rollout, including the completion of phase C of the vision by 2035, supported by the existing SESAR programme, which also supports the implementation of an optimised European airspace architecture and the 'fast tracking' of the deployment of U-space services from 2019. The two options for the rollout of technology enabling the completion of phase D are shown; option 1 requires an earlier start and thus industry and stakeholders' consensus and commitment.

Reaching the SESAR vision by 2040 instead of 2050 (or in any case earlier than 2050) would make it possible to reap crucial benefits about a decade earlier and at a lower cost, as explained in Chapter 6, thanks to cutting on transition costs and going straight to the performing solutions and organisation. However, achieving this will require new ways of working within SESAR, as well as an evolution in the regulatory framework to promote innovation, as described below.

- The new ways of working within SESAR would involve the following.
  - More agility: creating solutions through prototypes and demos developed

FIGURE 16. TARGET ROLLOUT OF SESAR



in smaller teams with shorter time frames; developing solutions by addressing service-related challenges without prejudging upfront what the optimal technical solution is; creating SESAR innovation labs to fast-track R&D, perform quick prototyping and incubate new ideas.

- Openness, in the form of increased collaboration between 'traditional' engineering domains and new entrants that are now likely to attract more capital.

- Coordination to reduce innovation cycles from about 30 years to about 5-10 years, focusing on disruptive innovation. To achieve this, the development and deployment of the integration of drones into the airspace, and in particular the development and implementation of U-space services, may be used as a 'laboratory' that can support faster life cycles in the manned aviation environment; in addition, 'sandboxing' between organisations may allow faster times to market.

• A regulatory framework that will support innovation — through market take-up, incentives for early movers and focus on delivery of services — is required, with an emphasis on what services should be provided and how, rather than on what technologies should be implemented.

This innovative approach would allow better connections and synchronisation between ground-based developments and the airborne industry, whose plans and expectations for the future are already known. This is described in the subsection below.

5.1.3 Critical changes in the airborne segment

Together with the strategy for and phased approach to rolling out SESAR, it is necessary to connect the SESAR vision with trends and projects in the airborne segment, which can serve as milestones on the route towards the implementation of phase D.

• **More autonomous aircraft.** The airborne manufacturing industry's contribution to increased automation will result in more aircraft automation and autonomy. The next step envisages a move from the current model of large aircraft with two pilots in the cockpit to a single crew member in the cockpit, that is, SPO. SPO is a response to societal expectations on the ultimate capability of a human to take over in the case of disruption in automation, while paving the way to full autonomous flight. Full autonomous flight (i.e. UAS for commercial flights) is an SPO remote use case, as the possibility of on-board pilot incapacitation must be taken into account.

Full autonomous flight could potentially be pioneered by the freight transportation industry. For instance, technical enablers of highly secure and robust command and control between aircraft and a remote control centre on the ground could be developed. SESAR should validate the seamless integration of autonomous aircraft into the ATM system both from a technical and an operational perspective. Fully autonomous flight will be supported by airborne self-separation and DAA functionalities.

- **Business trajectory.** The business trajectory is the European development of the ICAO TBO concept. With TBO, ATC is no longer based on where the aircraft is but on where the aircraft will be. One of the main enablers of TBO and part of the PCP is the synchronisation of the airborne-based and ground-based predictions of the aircraft trajectory, in the shape of the RBT or reference mission trajectory (RMT). The airborne industry has embraced the TBO concept, having produced a first certified product to support the i4D very large-scale demonstration.

  While TBO is a much needed evolution of current ATM, TBO will need to be inherent in U-space and is seen by the industry as key for ATM/UTM convergence resulting from further evolutions of the current business trajectory concept.

- **Urban air mobility.** The latest industry progress in battery technology and electric propulsion is prompting the emergence of a wide range of new air transportation applications, enabling even further increased efforts to reduce noise and CO_2 emissions. This development, among others, can help to make possible more operations in congested areas and opens the door to alternative responses to the increasing demand for transport in megacities. Urban air mobility features flying taxis operating at low and very low levels in suburban and urban areas, starting at present with vehicles such as helicopters and moving naturally towards more autonomous operations, alternative propulsion and new vehicle designs. There are a number of related projects around the world, some already experimenting with aerial prototypes. Urban air mobility will be one of the most demanding use cases for Uspace, and the related services will need to be validated by SESAR.

- **Digitalisation and connectivity.** System-wide information sharing, big data analytics, etc., are becoming the industry state of the art, bringing increased productivity and performance. The benefits for ATM of this major industry evolution have inspired the Tallinn declaration [58] and are duly recognised in the SESAR vision. In order for this vision to materialise, SESAR needs to prompt the validation of transverse ATM solutions for cybersecurity, full implementation of SWIM services, datalink and broadband connectivity (satcom/L-DACS).

5.1.4 Supporting the implementation of an optimised European airspace architecture

The Airspace Architecture Study, developed by the SJU with support from the Network Manager and delivered to the Commission on 5 February 2019, aims to address the capacity challenge by, for the first time, considering developments in airspace, operations and technical in combination with proposed changes to service provision

[58] Towards the Digital European Sky. A Joint Industry Declaration. (https://www.sesarju.eu/sites/default/files/documents/reports/Joint%20Declaration%20-%20Towards%20the%20Digital%20European%20Sky.pdf)

FIGURE 17. AIRSPACE ARCHITECTURE STUDY TRANSITION STRATEGY

2025

- ECAC-wide implementation of **cross-border Free Route, air-ground** and **ground-ground** connectivity
- Launch **airspace re-configuration** supported by **Operational Excellence** Programme
- Set up an **enabling framework** for **ADSP, capacity-on-demand** service and **rewards for early movers**, first ADSP is certified

2030

- Implement **virtual centres** and **dynamic airspace configuration** at large scale
- Gradual transition towards **high levels of automation** supported by SESAR Solutions
- **Capacity-on-demand** arrangements implemented accross Europe
- **New ATM data service provision model** is implemented across Europe

2035

- Transformation to **flight/flow centric operations**
- **Trajectory-based operations**
- **Service-oriented** air traffic management

supported as needed by the relevant regulatory measures.

The objective of this study is to propose a future European airspace architecture, with an associated transition strategy, to start to address the capacity shortage in the short term, and also to develop an architecture robust enough to ensure the safe, seamless and efficient accommodation of all air traffic in the long term. Making use of the expected delivery of the relevant R&D carried out under in the SESAR 2020 programme and outlined in the present edition of the Master Plan, the study targets completion and full implementation by 2035, that is, the same date by which the current SESAR programme is expected to have been fully deployed and phase C of the vision delivered (see Chapter 2).

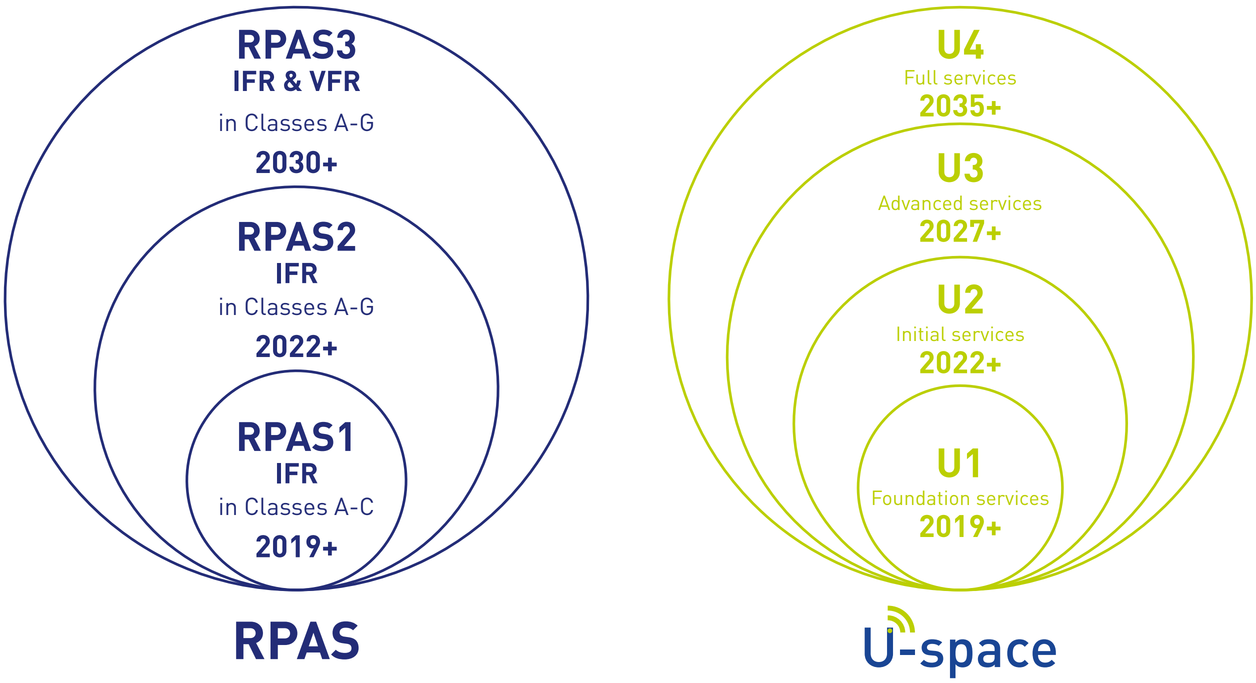
The proposed transition strategy to implement the recommendations of the Airspace Architecture Study consists of three steps of 5 years, each step paving the way for the next.

FIGURE 17, extracted from the study, illustrates the main elements of each 5-year period during the transition, supported by the technology delivered by the SESAR programme and outlined in this edition 2019 of the Master Plan.

There are three specific conditions that should be considered in order to secure this implementation timeline.

- **Capacity-on-demand agreements.** These will ensure the continuity of ATS by enabling more dynamic temporary delegation of the provision of ATS to an alternative centre with spare capacity.
- **New model for ATM data service provision.** This should support the progressive shift to a new service delivery model for ATM data, through the establishment of dedicated ADSPs. The ATM data services would provide the data and applications required to provide ATS and include flight data-processing functions such as flight correlation, trajectory prediction, conflict detection and conflict resolution, and arrival management planning. These services rely on underlying integration services for weather, surveillance and aeronautical information. The maximum scope of service delivery by ADSPs would cover

FIGURE 18. U-SPACE ROADMAP



the ATM data services (e.g. flight data processing) needed to realise the virtual defragmentation of European skies and would include the provision of AIS, MET and CNS services.

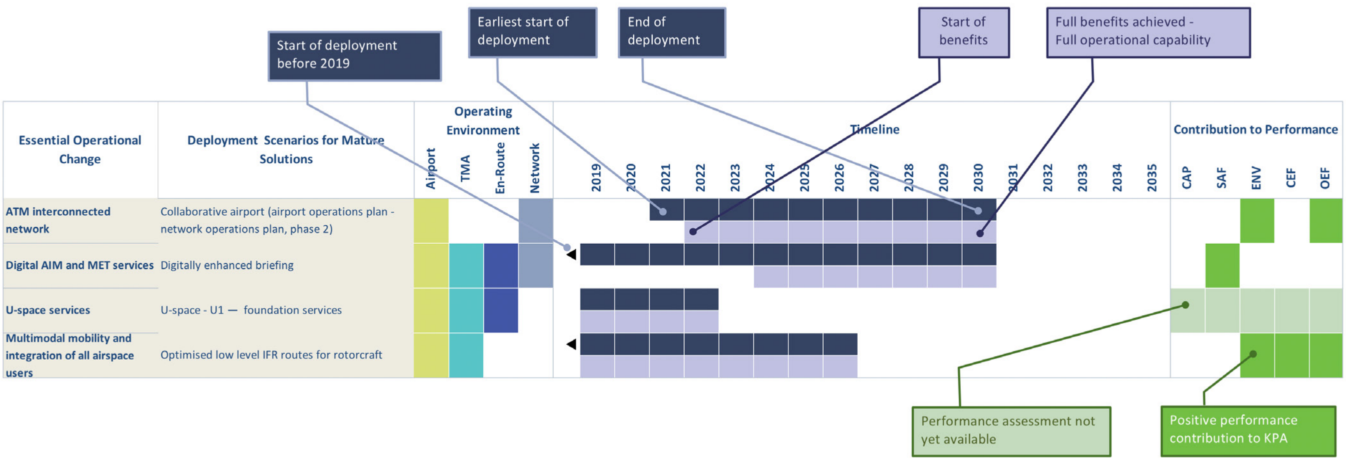
- **Targeted incentives for early movers.** Specific incentives should be put in place for those actors that implement recommended operational improvements or that shift towards innovative delivery models, with a focus on early movers, in order to initiate the transition. This is further detailed in Chapter 6.

5.1.5 Synchronising ATM transformation and the drones roadmap

One of the key missions of the SESAR programme, reflected in the Master Plan, is to enable the safe and efficient integration of all aerial vehicles into both controlled and uncontrolled airspace. In accordance with the adopted drones roadmap, the goal is to ensure that drone operations (both UAS and RPAS, including military) are managed as routine operations by 2035 and the delivery of phase C of the vision, as illustrated in **FIGURE 18** (and in line with **FIGURE 16** with regard to U-space).

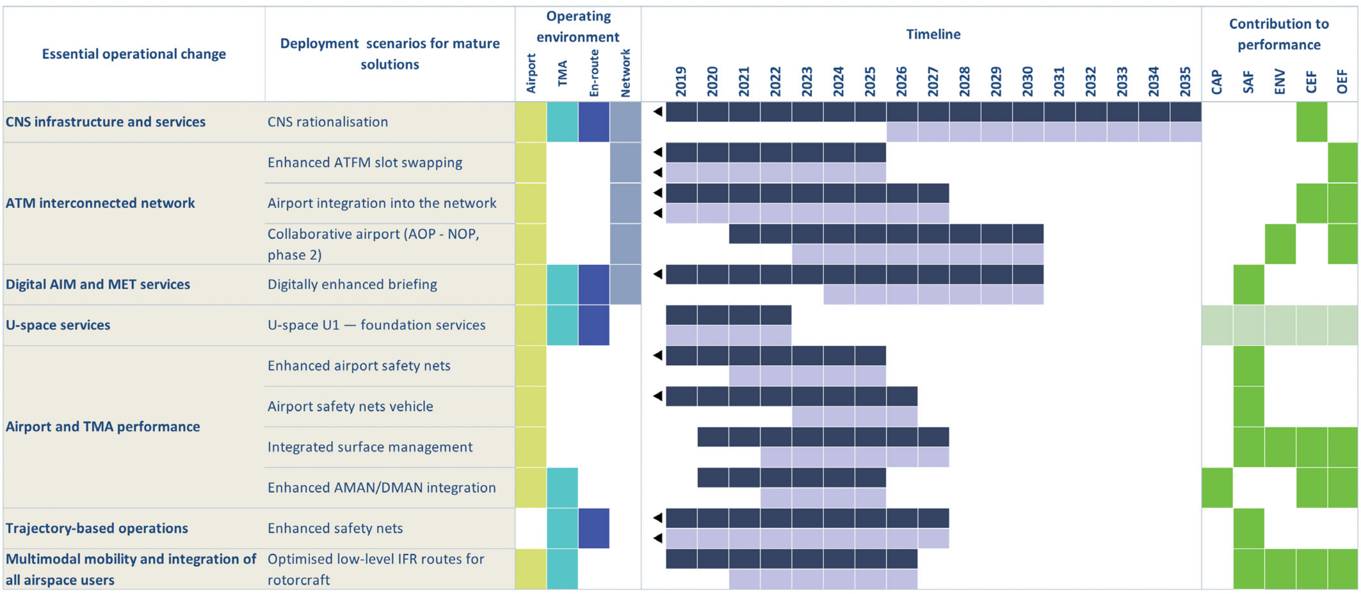
In accordance with the same drone roadmap, full integration of U-space with ATM is targeted for 2035+, which corresponds to option 1 for the delivery of the SESAR vision, which envisages the development and implementation of U-space services being used as a 'laboratory' to support the gradual implementation of faster life cycles in the manned aviation environment.

FIGURE 19. INTERPRETATION OF DEPLOYMENT SCENARIOS



NB: CAP, capacity; CEF, cost efficiency; DS, deployment scenario; ENV, environment; OEF, operational efficiency; SAF, safety

FIGURE 20. DEPLOYMENT SCENARIOS FOR MATURE SOLUTIONS



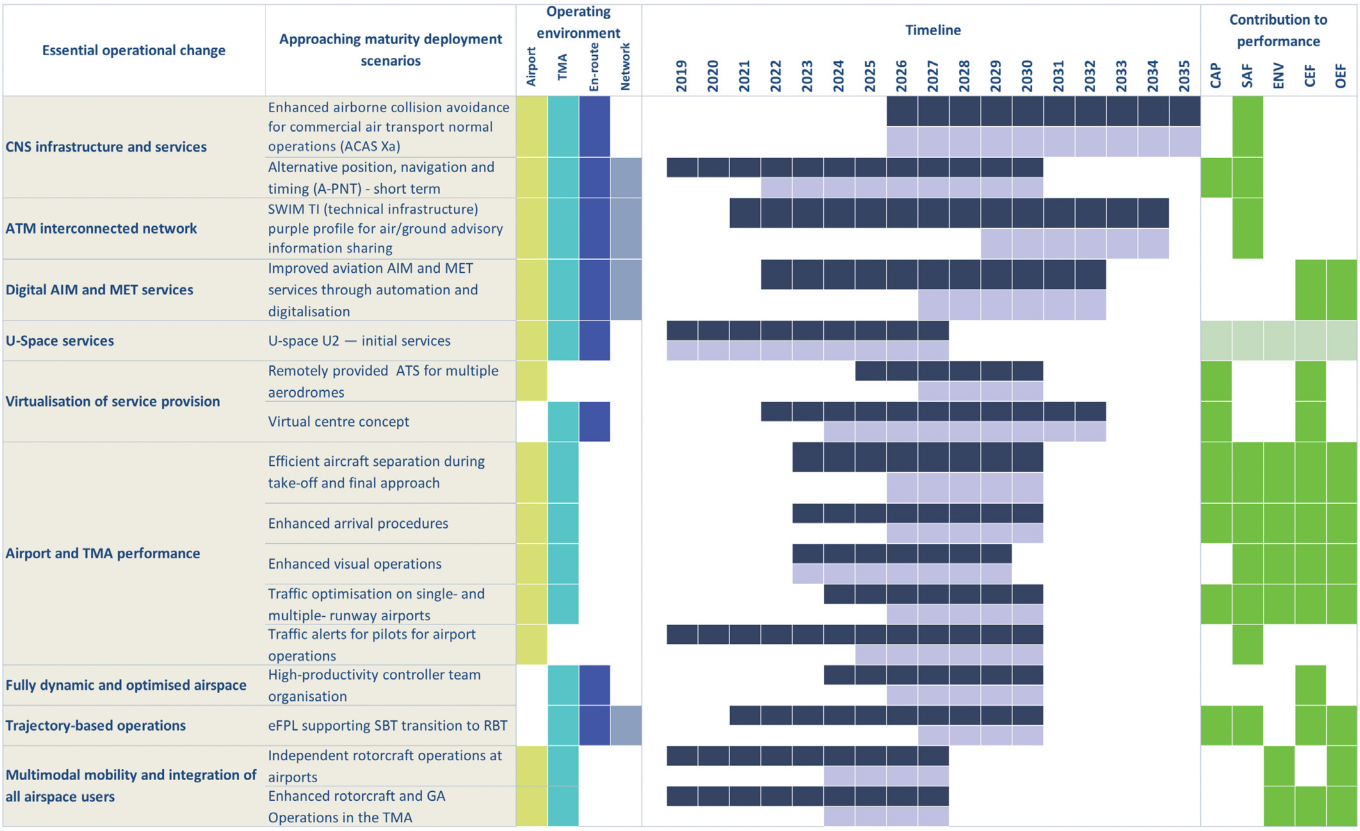
5.2 DEPLOYMENT SCENARIOS

This section presents deployment scenarios for changes that are in the pipeline towards deployment and that are associated with EOCs, as described in Chapter 4 [59].

The deployment scenarios are based on mature SESAR Solutions proposed for deployment, and solutions approaching maturity, as described in Section 4.2. Experience gained from a first wave of synchronised deployment emphasises the importance of planning deployment only of Solutions that are sufficiently mature. For each deployment scenario, the operating environment(s) in which performance gains can be realised are indicated.
A rollout time is also provided: the timescales for the start of deployment and the end of deployment are shown in blue, and the timescales for the start of benefits at a given place/site and the delivery of the full benefit are shown in purple in **FIGURE 19**. Contribution to performance is indicated on the right-hand side of the figure. When the contribution is positive, it is shown in green.

[59] For a full account of the links between deployment scenarios and solutions, please refer to Annex A.

FIGURE 21. DEPLOYMENT SCENARIOS FOR SOLUTIONS APPROACHING MATURITY



5.3 STAKEHOLDER ROADMAPS SUPPORTING ESSENTIAL OPERATIONAL CHANGES

This section provides a deployment roadmap for each stakeholder category (ANSPs, airport operators, airspace users and the Network Manager). The aim is to provide a clear account for each stakeholder category of the main ATM investments that should be planned in the coming decade for technology that is expected to reach maturity by the end of 2020.

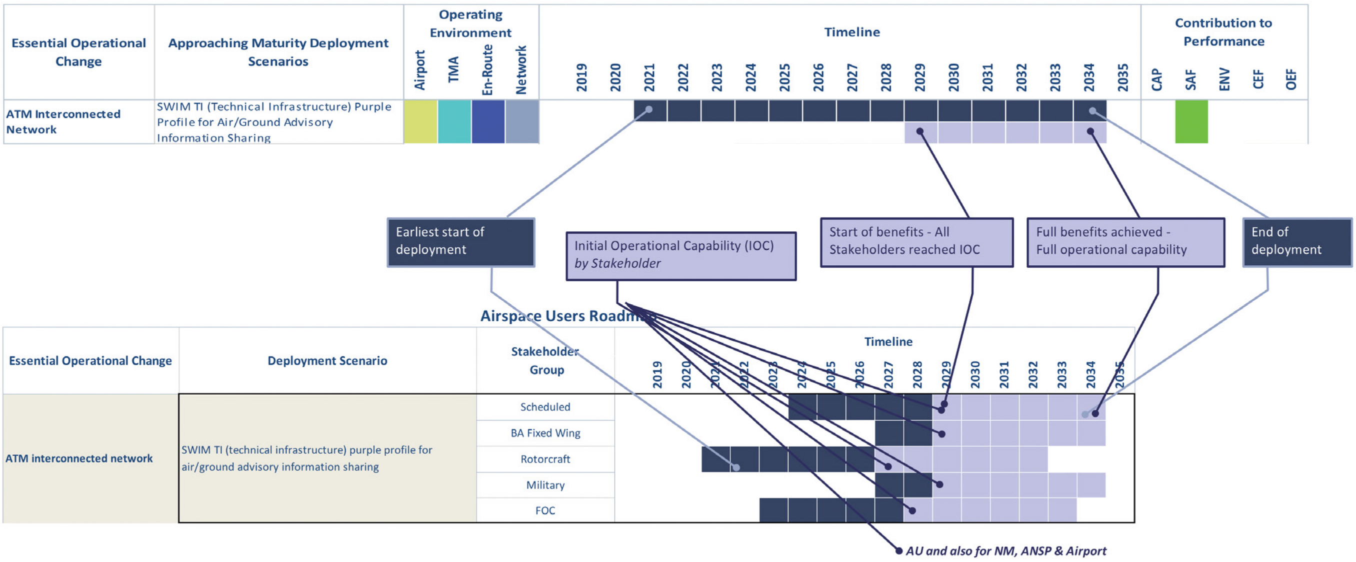
Each roadmap provides, for each EOC, the planned timelines for the relevant deployment scenarios identified in Section 5.2.

Optimising performance benefits also requires synchronised deployment planning among the various stakeholders to avoid situations where investments made by one stakeholder cannot deliver benefits because another has not yet made the corresponding required change.

The stakeholder roadmaps show the deployment scenarios in relation to specific time frames. For each deployment scenario, two time frames are to be considered (**FIGURE 22**).

- The blue shading represents the period from the earliest start of deployment date of the associated deployable elements until initial operational capability (IOC) is reached. When considering implementation, additional aspects such as investment cycles, business models and constraints need to be taken into account within this period. Stakeholders might have different start of deployment and initial operational capability dates for a given deployment scenario, because each stakeholder will have one or more elements to implement at separate locations. Once a stakeholder has deployed all required elements at one of the intended deployment locations, it is deemed that initial operational capability has been reached and the blue shading ends. In the meantime, the rest of the deployment elements continue to be implemented by each stakeholder in the

FIGURE 22. **INTERPRETING THE STAKEHOLDER DEPLOYMENT ROADMAPS AND THE LINK TO THE DEPLOYMENT SCENARIOS**

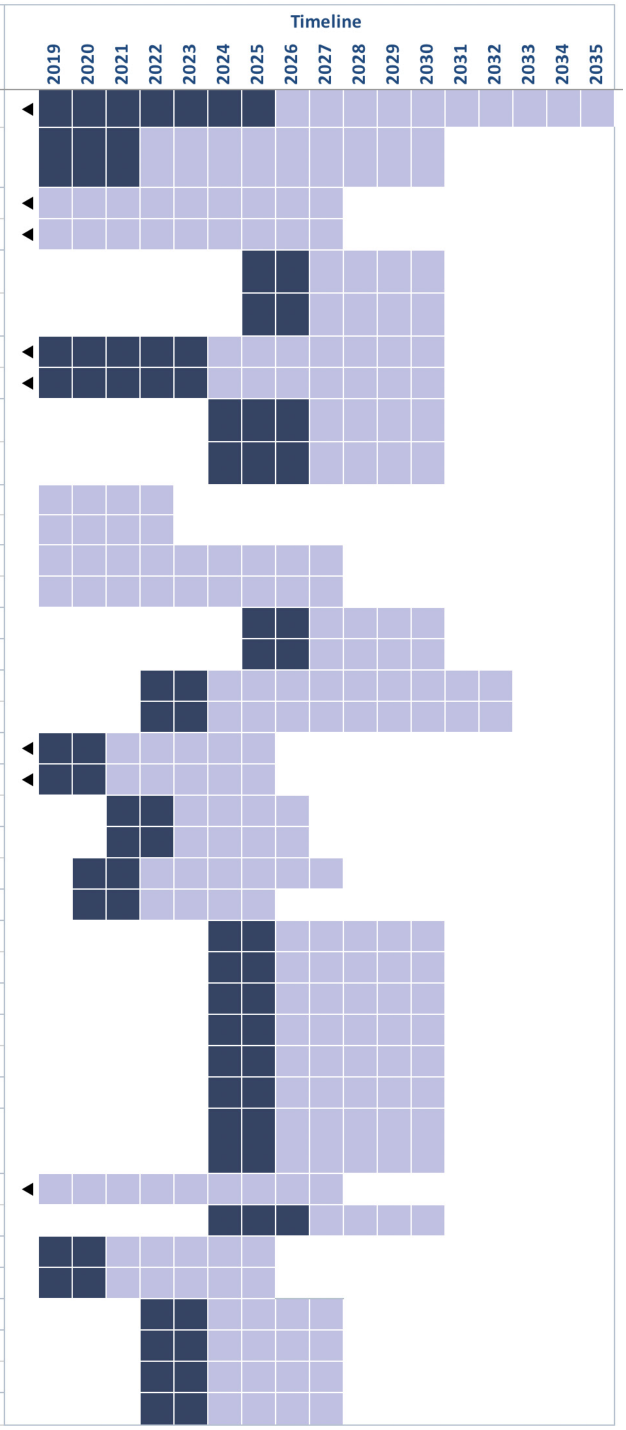


remaining deployment locations. When all stakeholders have reached IOC in one deployment location, this coincides with the start of benefits date for the deployment scenario.

- The purple shading represents the time required for the remaining elements to reach initial operational capability in their designated deployment locations. Normally, a deployment scenario needs to be deployed at several designated deployment locations. Once all required elements have been deployed at their designated locations by a stakeholder, the purple shading ends,

FIGURE 23. ANSP ROADMAP

Essential operational change	Deployment scenario	Stakeholder group
CNS infrastructure and services	CNS rationalisation	Civil
	Alternative position, navigation and timing (A-PNT) - short term	Civil
ATM interconnected network	Airport integration into the network	Civil
		Military
	SWIM TI (technical infrastructure) purple profile for air/ground advisory information sharing	Civil
		Military
Digital AIM and MET services	Digitally enhanced briefing	Civil
		Military
	Improved aviation AIM and MET services through automation and digitalisation	Civil
		Military
U-space services	U-space U1 — foundation services	Civil
		Military
	U-space U2 — initial services	Civil
		Military
Virtualisation of service provision	Remotely provided ATS for multiple aerodromes	Civil
		Military
	Virtual-centre concept	Civil
		Military
Airport and TMA performance	Enhanced airport safety nets	Civil
		Military
	Airport safety nets vehicle	Civil
		Military
	Integrated surface management	Civil
	Enhanced AMAN/DMAN integration	Civil
	Efficient aircraft separation during take-off and final approach	Civil
		Military
	Enhanced arrival procedures	Civil
		Military
	Traffic optimisation on single- and multiple-runway airports	Civil
		Military
Fully dynamic and optimised airspace	High-productivity controller team organisation	Civil
Trajectory-based operations	Enhanced safety nets	Civil
	eFPL supporting SBT transition to RBT	Civil
Multimodal mobility and integration of all airspace users	Optimised low level IFR routes for rotorcraft	Civil
		Military
	Independent rotorcraft operations at airports	Civil
		Military
	Enhanced rotorcraft and GA operations in the TMA	Civil
		Military



indicating full operational capability. When all stakeholders (including sub-stakeholders) have completed deployment of all the required elements at their respective deployment locations to coincide with the end of deployment date, the full benefits of the deployment scenario are achieved.

5.3.1 The ANSP roadmap

FIGURE 23 presents the deployment roadmap for ANSPs, with a breakdown between civil and military ANSP sub-stakeholders [60].

[60] This category includes MET service providers for each sub-stakeholder and also U-space service providers.

FIGURE 24. AIRPORT OPERATOR ROADMAP

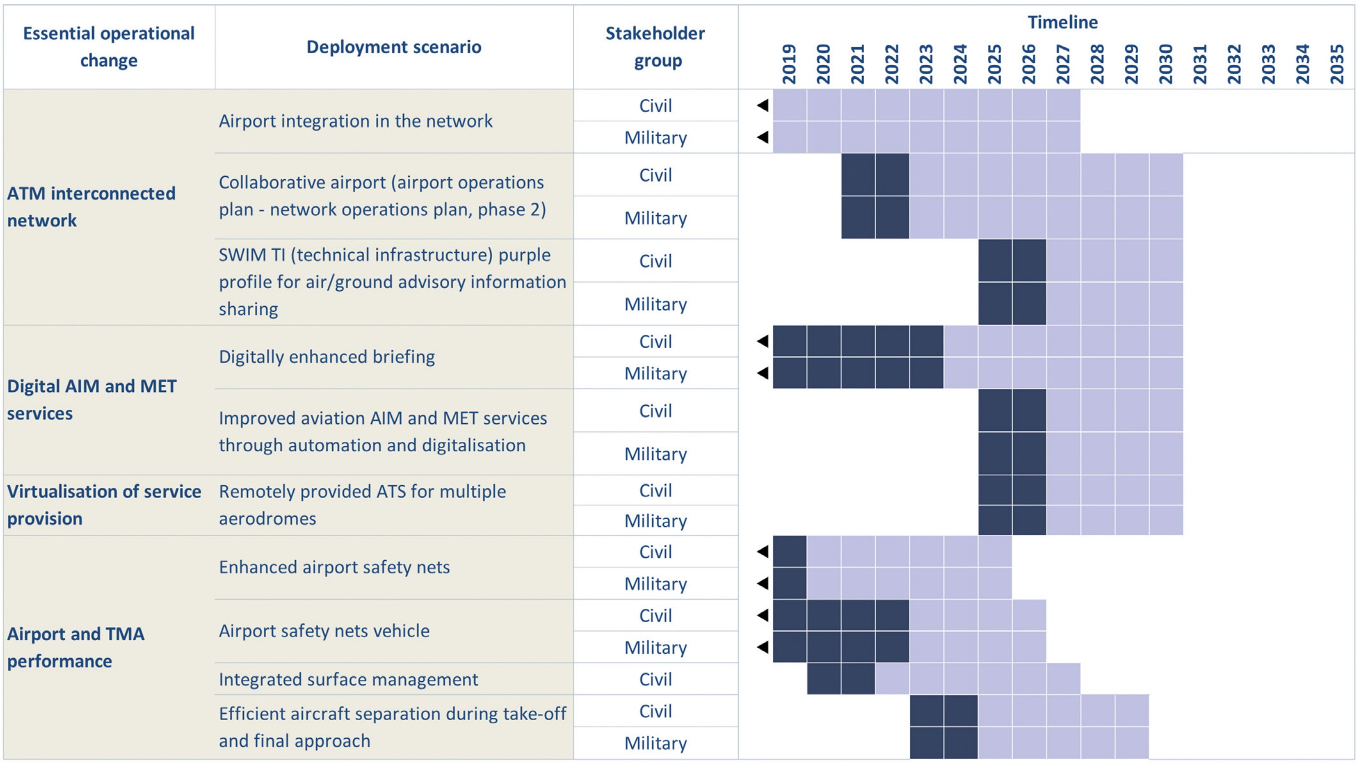
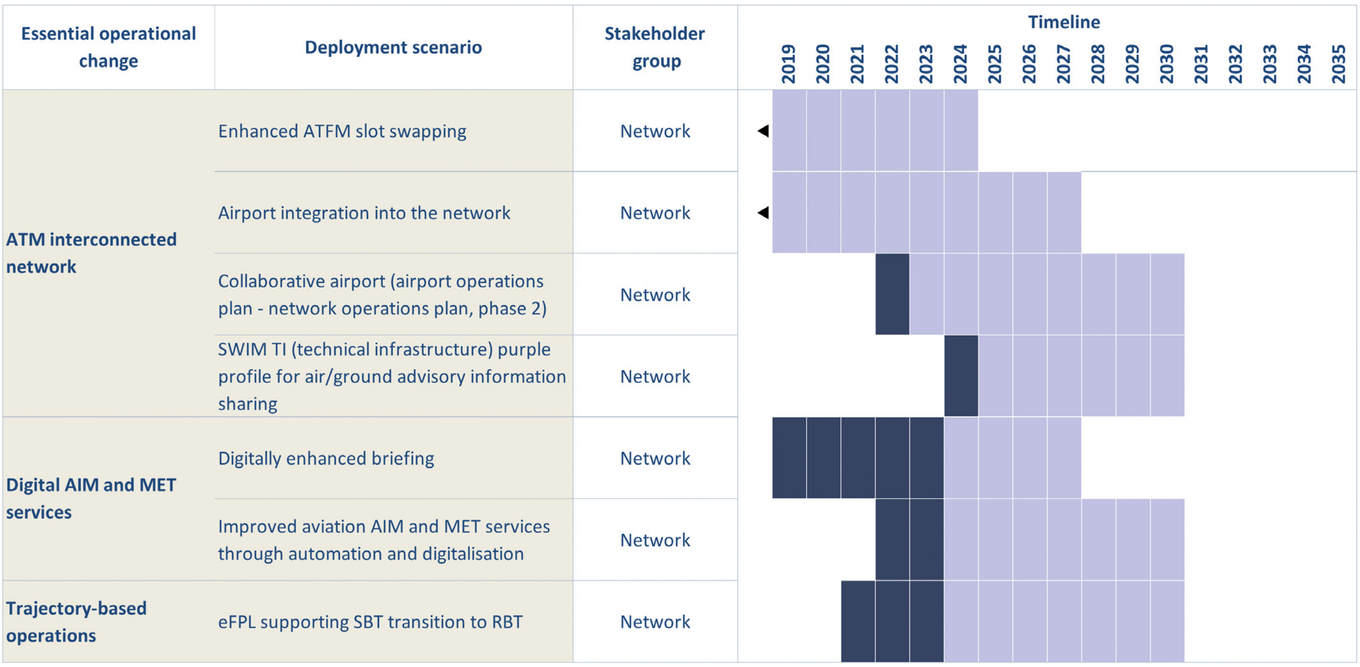


FIGURE 25. NETWORK MANAGER ROADMAP



5.3.2 The airport operator roadmap

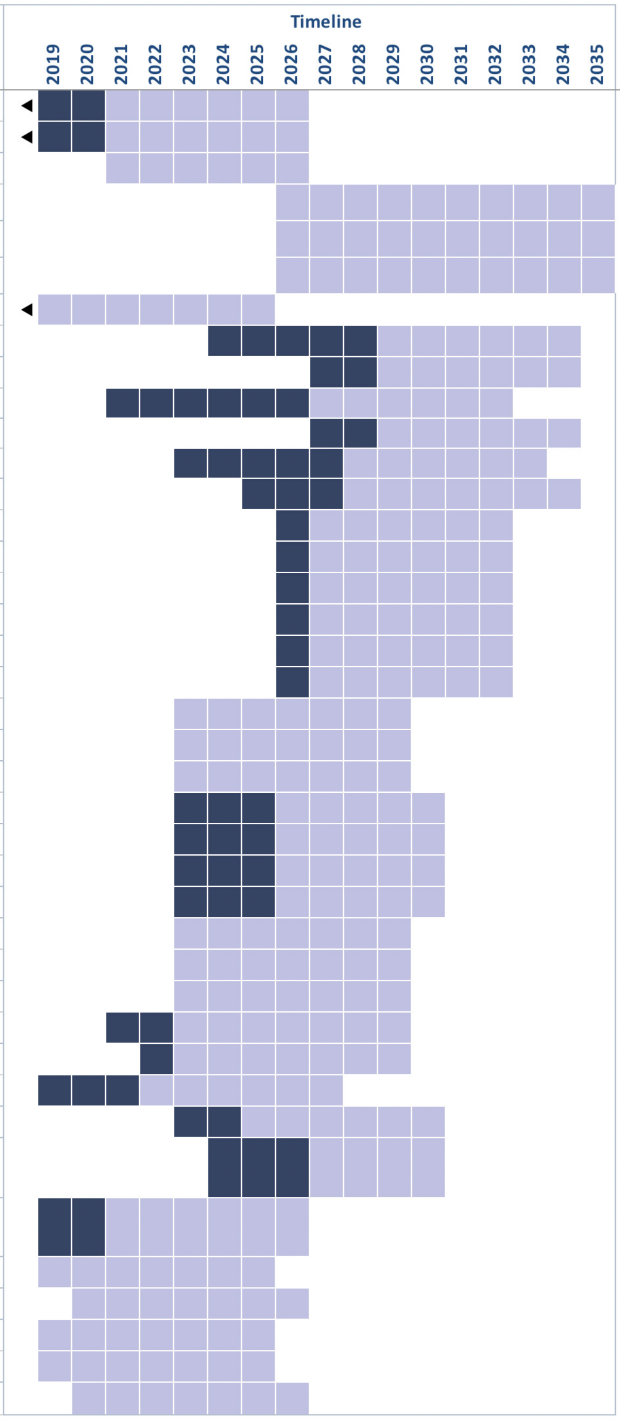
FIGURE 24 presents the airport operator deployment roadmap, with a breakdown between civil and military sub-stakeholders.

5.3.3 The Network Manager roadmap

FIGURE 25 presents the Network Manager deployment roadmap.

FIGURE 26. AIRSPACE USERS ROADMAP

Essential operational change	Deployment scenario	Stakeholder group
CNS infrastructure and services	CNS rationalisation	Scheduled
		BA Fixed Wing
		Military
	Enhanced airborne collision avoidance for commercial air transport normal operations (ACAS Xa)	Scheduled
		BA Fixed Wing
		Military
ATM interconnected network	Enhanced ATFM slot swapping	FOC
	SWIM TI (technical infrastructure) purple profile for air-ground advisory information sharing	Scheduled
		BA Fixed Wing
		Rotorcraft
		Military
		FOC
		WOC
Digital AIM and MET services	Improved aviation AIM and MET services through automation and digitalisation	Scheduled
		BA Fixed
		GA
		FOC
		Military
		WOC
Airport and TMA performance	Efficient aircraft separation during take-off and final approach	Scheduled
		BA Fixed Wing
		Military
	Enhanced arrival procedures	Scheduled
		BA Fixed Wing
		GA
		Military
	Enhanced visual operations	Scheduled
		BA Fixed Wing
		Rotorcraft
	Traffic alerts for pilots for airport operations	Scheduled
		BA Fixed Wing
		Rotorcraft
		Military
Trajectory-based operations	eFPL supporting SBT transition to RBT	FOC
Multimodal mobility and integration of all airspace users	Optimised low-level IFR routes for rotorcraft	Rotorcraft
	Independent rotorcraft operations at airports	Rotorcraft
		Military
	Enhanced rotorcraft and GA operations in the TMA	Rotorcraft
		GA
		Military



5.3.4 The airspace user roadmap

FIGURE 26 presents the airspace user deployment roadmap, with a breakdown of the following stakeholder groups: scheduled aviation, business aviation (BA fixed wing), rotorcraft, general aviation (GA), FOCs, WOCs and military aviation.

5.4 INFRASTRUCTURE EVOLUTION IN RELATION TO CNS AND SPECTRUM

5.4.1 CNS strategy

Technologies on the ground, in space and on board the aircraft are critical technical enablers for the EOCs required to create the future ATM system. Performance requirements are becoming increasingly demanding, resulting in a need to move to high-performing and integrated air and ground CNS infrastructure and services enabling better performing aviation for Europe. This necessary evolution will follow the key directions set out below.

5.4.1.1 A change in focus from physical assets to delivery of services

In the context of the digital transformation of ATM and the move towards a data ecosystem, the CNS infrastructure needs to gradually move towards being provided as a service rather than operated as physical assets. This will enable the required flexibility to deal with the growing complexity of technological life cycles. It will also create a business environment that favours performance at all levels. Business models set up to operate the services could differ between COM, NAV and SUR services and even within COM, NAV and SUR services. Multiple service providers, including military providers, could offer their services in competition. Customers and providers could be the same or distinct.

5.4.1.2 Performance-based and integrated CNS

A performance-based CNS approach makes it possible to evolve from system/technology-based operations, where systems/technologies are prescribed, towards the delivery of performance-based services, which specify what is to be achieved within a specific environment based on the operational requirements and considering CNS as a whole and integrated system. This leaves to the service providers the choice of systems/technologies that can achieve the specified performance, taking into account their service delivery models and local specificities. This also enables airspace users to rationalise airborne systems by customising the required airborne equipage to their aircraft, taking into account their operation models. Considering the CNS infrastructure and services in an integrated way makes it possible to benefit from synergies between the classical CNS pillars, so that for example, a system designed for communication can provide services to contribute to the resilience of a navigation service.

5.4.1.3 Combined satellite-based, airborne and ground-based CNS

Satellites play and will continue to play an increasing role in CNS domains, delivering improved navigation performance, new surveillance capabilities and the data exchanges required for trajectory management.

The global/regional nature of satellite constellation allows for a flexible and global approach to service provision, including for remote areas. The space segment as a key part of CNS capability, in combination with airborne and ground-based infrastructure, will support a coherent rationalisation of the overall CNS infrastructure while contributing to the delivery of improved services. The evolution of satellite constellations will support current and future ATM operations for all phases of flight.

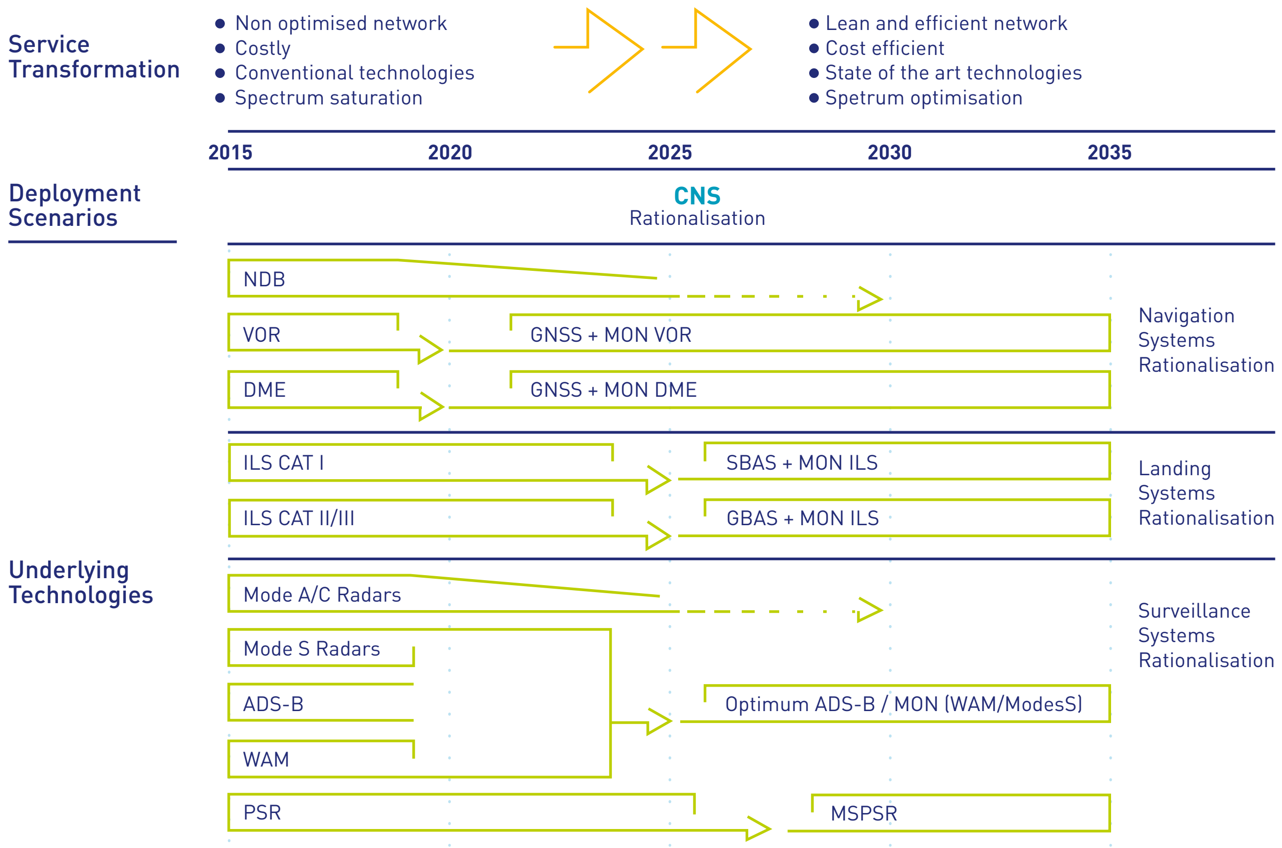
5.4.1.4 Rationalised infrastructure

CNS rationalisation will lead to network optimisation, following the implementation of new functionalities and/or technologies to support high performance and efficiency (in terms of cost, spectrum, etc.). The service-oriented approach and the integrated CNS will foster this process. Military infrastructure and systems will 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.

This rationalisation will be supported by the implementation of the MON, mainly composed of legacy systems/services, to a level where it will operate as a backup for the CNS backbone, continuing to provide effective support in the event of the failure of a component of the backbone (e.g. loss of GNSS).

The potential for optimisation and rationalisation is recognised for the ground

FIGURE 27. **RATIONALISED INFRASTRUCTURE**



systems NDB, VOR, DME, ILS, Mode A/C/S radars, high-frequency and VHF voice, and VHF datalink mode 2 (VDL 2), by civil ANSPs, as shown in **FIGURE 13** ([61]).

While datalink will become the primary means of communication, voice will continue to be used for time-critical and non-routine messages as well as for communications with specific aircraft. In the long term, VHF voice will start to be decommissioned, but, to maintain voice services adapted to the new concept of operations, it will be replaced by digital mobile technology (e.g. voice over IP), which will ensure the continuity of voice services alongside datalink and will also provide new voice connection functions (e.g. routable features such that voice exchanges can take place from anywhere).

5.4.1.5 Safe, secure and resilient infrastructure

Cyber-threats have emerged over recent decades and are now a reality, including for aviation, air transport and ATM: Europe's critical infrastructures are attractive targets for cyberattacks. A security breach in CNS technology is considered a safety breach in ATM operations.

Mitigating cybersecurity risks in CNS systems requires implementing high-level security requirements in each of the technological solutions and in the CNS system as a whole, leading to an evolution of the architecture to enable resilience against cyberattacks.

Safety in aviation is always a must; the evolving CNS will continue to meet the high-level safety requirements.

([61]) This figure represents already agreed rationalisation plans for the navigation and surveillance domains. Rationalisation opportunities in the communication domain have not been agreed yet but could be envisaged in the future, together with further rationalisation opportunities arising from the adoption of digital technologies.

5.4.1.6 Increased civil-military synergies and dual use

The need for the military to safely operate with a high degree of response and flexibility calls for an appropriate level of interoperability with civil aviation. This makes it essential for military requirements to be taken into account when implementing improvements in the CNS domain.

Early engagement with military authorities, within the CNS enhancement programme, is critical for understanding the technical challenges relating to the incorporation of capabilities for military platforms, and for identifying opportunities for increasing synergies between civil and military domains and technologies (dual use, performance, network access, cybersecurity, etc.). The changes to the CNS infrastructure should also take into account the need for maintenance of residual legacy infrastructure based on specific military needs.

Civil-military cooperation has strong potential for supporting a rationalised and resilient CNS infrastructure: data sharing will improve performance and assist in the rationalisation of SSR mode A/C radars. A robust data-sharing network with relevant cyber-protection and cyber-resilience is essential.

5.4.1.7 Performance equivalence

States have full authority to determine their own criteria and practices for validating the performance and safety of their state aircraft. Considering SES developments and in order to enable safe and effective access to airspace, national military authorities are expected to demonstrate the compliance of their state aircraft with civil ATM/CNS requirements. Since certification against the civil standard is not always achievable (e.g. in the case of use of military GNSS), the introduction of performance equivalence (PE) is seen as a possible acceptable means of compliance. Preliminary results show that this may be possible but that regulations need to be more strongly defined as performance-based. Furthermore, the PE process may not solve all the compliance issues for state aircraft, and the utility of the process is still to be assessed. Consequently, solutions (e.g. exemptions) to handle non-compliant state aircraft should also be inv qstigated and incorporated where necessary.

5.4.1.8 Efficient use and long-term availability of suitable radio frequency spectrum

The availability of radio spectrum is fundamental to delivering the CNS infrastructure necessary to achieve the safe and efficient management of all classes of aviation. It will be a vital enabler in delivering the components of the Master Plan. At the same time, the sector seeks to exploit developing technologies to deliver the overall aims of a more efficient, cost-effective and safe infrastructure, necessary to meet future aviation needs (e.g. unmanned aviation).

The SESAR spectrum strategy aims to secure the long-term availability of suitable radio spectrum to meet all of Europe's future objectives for aviation through cooperative engagement at global level. Spectrum efficiency is a recurring challenge that can be addressed through the deployment of updated technology. To deliver this aim, the vision seeks to set out the principles through which aviation can benefit from a sustainable long-term future for aeronautical spectrum, namely:

- periodical assessment of the saturated bands and investigation of optimum use of the available spectrum (e.g. the 960-1215 MHz band), at pan-European level;
- review of the current use and improvements with regard to efficiency (e.g. VDL 2), at pan European level;
- adoption of a holistic approach consistent with the performance-based approach to COM, NAV and SUR;
- transformation of the current reactive process to deal with threats to a proactive process, supported by a long-term view and improved collaboration with all aviation stakeholders.

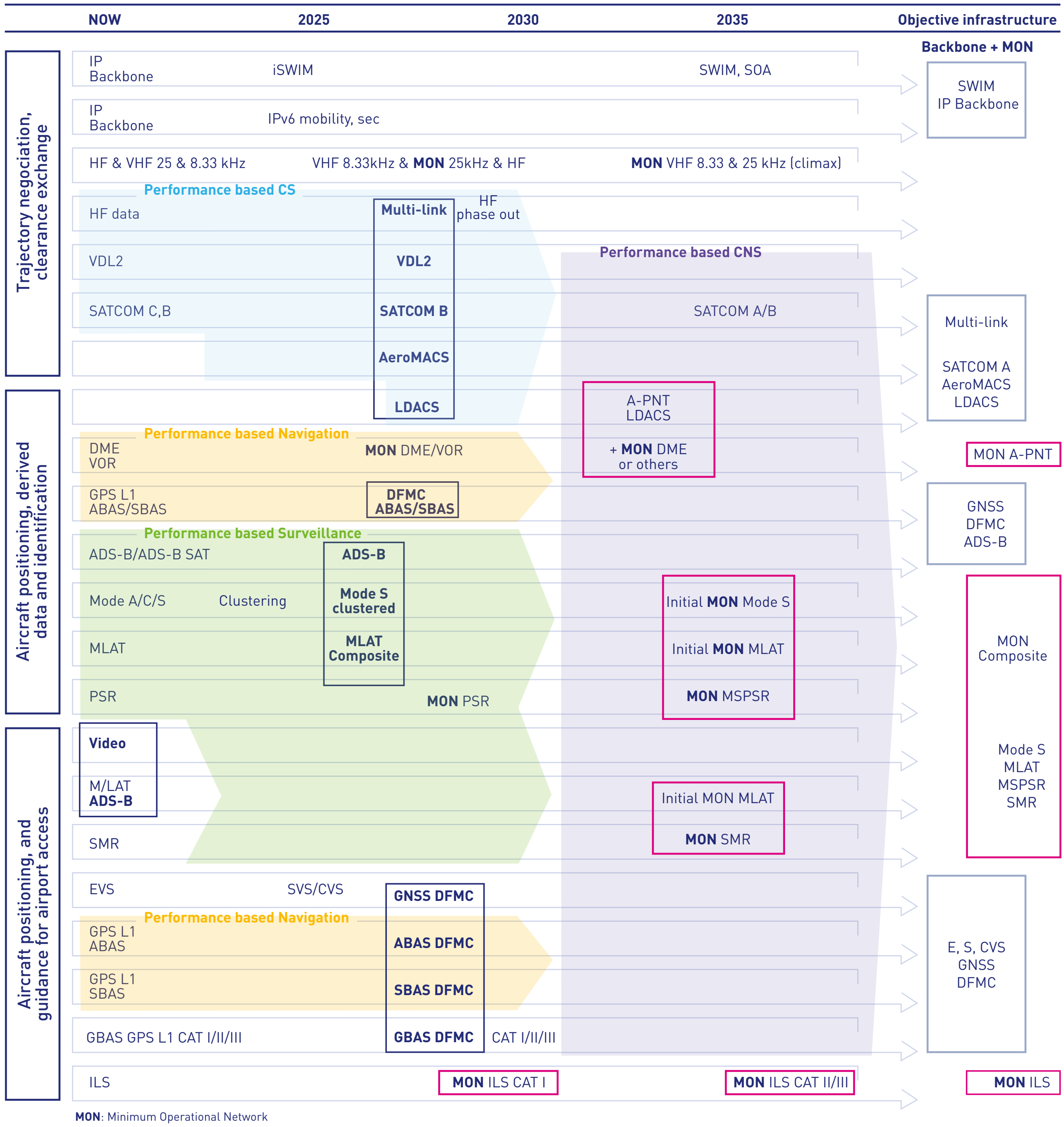
5.4.2 CNS roadmap

The roadmap is driven by the move towards performance-based CNS. This will allow the ATM CNS to evolve from system-based operations to the delivery of CNS services. Integrating these existing concepts into a harmonised performance-based CNS framework, including appropriate performance metrics, would maximise the cross-domain opportunities and synergies and would support various airspace concepts. A unified performance-based CNS concept would also enable a better understanding of the CNS environment, currently perceived by airspace users and service providers as a complex system. The development of a performance-based CNS framework could also support flexibility for ANSPs and could enable them to define their own CNS service delivery models. Finally, such a framework could enable the rationalisation of airborne systems through the customisation of the required airborne equipage to suit the aircraft and local specificities, as well as the operator's business model.

FIGURE 28 shows the CNS roadmap, based on a backbone infrastructure (composed of SWIM, multilink services, DFMC GNSS and ADS-B) and complemented by the MON. Technologies or types of technologies (represented by arrows) have been grouped under the functional domains trajectory negotiation, clearance exchange; aircraft positioning derived data and identification; and aircraft position and guidance for airport access. The arrow's colour is determined by the framework under which the technology is implemented (i.e. performance-based communication, performance-based navigation, performance-based surveillance or, in the future, performance-based CNS). The components of the infrastructure backbone have been identified on the right-hand side of the figure using grey boxes, whereas the technology expected to be rationalised and to form the components of the MON are identified with the prefix 'MON'. **FIGURE 28** identifies the main applications supported by the underlying technologies.

The figure is organised into approximately 5-year blocks: the present to 2025, 2025-

FIGURE 28. CNS ROADMAPS FOR BACKBONE INFRASTRUCTURE



2030, 2030-2035 and beyond 2035. These time references should be understood as indicative and not as firm implementation dates. The objective of this roadmap is not to provide a project management plan for the implementation of the future CNS but, rather, to provide an executive view of which CNS applications and infrastructures should be ready by when.

The scope of the roadmap is limited to the safety-of-life applications; therefore, some non-safety-of-life applications mentioned earlier are not included in the roadmap (e.g. open connectivity and the application based on 3G/4G/5G networks).

5.5 STANDARDISATION AND THE REGULATORY VIEW

To deploy the SESAR EOCs required to build the future European ATM system, there is a need for appropriate regulations, technical specifications and means of compliance supported by standards. 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 manner. When regulations and standards are necessary to ensure the coordinated or harmonised deployment of the EOCs, early identification of those needs will be important. This will allow the various standardisation organisations and EASA to plan sufficiently in advance to be able deliver as required to support the envisaged deployment.

5.5.1 Harmonisation and synchronisation

For the purposes of this subsection, the term 'harmonisation' refers to the process of creating a consistent and convergent framework of common rules, specifications and procedures that enable uniform deployment of the SESAR Solutions across Europe. As used in this subsection, 'harmonisation' is achieved through regulatory action, technical specifications and means of compliance established by EASA, and appropriate standardisation activities (by EUROCAE, European standardisation organisations, Eurocontrol and military organisations), and it supports uniform implementation and standardised oversight actions.

The synchronisation of the deployment of EOCs is expected to be accomplished by Commission regulations and supported by incentives. The term 'synchronisation' is therefore used in the same meaning as in Commission Implementing Regulation (EU) No 409/2013 [62] on the definition of common projects. The requirement for future synchronised deployment is not explicitly included among the needs identified here, which focus on harmonisation aspects. The needs for synchronisation and financial incentive mechanisms are discussed in the business view in Chapter 6 (see Section 6.3).

Further harmonisation issues or initiatives concerning the EU and Federal Aviation Administration (FAA) are addressed in Chapter 4.

5.5.2 Identifying the needs

A systematic review of the SESAR Solutions and the underlying system enablers has been conducted as part of the development process in order to identify any standardisation and regulatory needs to support harmonised deployment. The review looked at the following:

[62] Commission Implementing Regulation (EU) No 409/2013 of 3 May 2013 on the definition of common projects, the establishment of governance and the identification of incentives supporting the implementation of the European Air Traffic Management Master Plan, OJ L 123, 4.5.2013, p. 1–7.

- technical and operational changes that involve physical interfaces, or the exchange of data, between different systems, operating in different stakeholder frameworks;

- the introduction of changes at stakeholder level or across stakeholders;

- changes to roles and responsibilities particularly associated with automated and digital systems;

- the allocation of specific performance requirements to different systems and constituents within and between stakeholder frameworks;

- prevention of monopolistic positions and support for new entrants to the aviation market.

Other objectives of harmonisation, as identified in the EASA basic regulation [63], are associated with the need to ensure safety, the free movement of goods, persons and services; the need to achieve cost-efficient regulation and certification at European level is also considered.

5.5.3 Standardisation and regulatory needs

This subsection provides a high-level view of the identified standardisation and regulatory needs currently envisaged in support of the deployment of the EOCs. It is important to acknowledge that such needs are those identified at the moment of adoption of this edition of the Master Plan. A number of the proposed SESAR Solutions in the EOCs are still subject to validation and consequently open to potential revision during the R&D phase, which may have an impact. The final identification of the standardisation and regulatory needs will be dependent upon the full definition of the concepts and the validation results. 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). This regular update enables regulations, technical specifications, means of compliance and mature standards, taking into account society's needs and public interests, to be developed in a timely manner, thus permitting the appropriate, harmonised deployment of the EOCs.

FIGURE 29 summarises the harmonisation needs for the EOCs. It indicates where a need for regulatory and standardisation activities has been identified. The rolling development plan (RDP) maintained by the European ATM Standards Coordination Group (EASCG) [64] indicates the progress made on either updating existing standards or the development of new standards for the traditional ATM community, while the RDP of the European UAS Standards Coordination Group (EUSCG) [65] does the same for UAS.

The ECSCG [66] was created in Oct 2018 dealing with cybersecurity-related standardisation and advises EASA and the European Commission. However, at the time of this edition of the Master Plan, it has not yet published an RDP.

The definition of the required regulations, technical specifications and means of compliance and progress on developing them are addressed in the actions included in the European Plan for Aviation Safety [67]. The plan also identifies specific subject areas that will require regulatory attention in the future (e.g. avoidance of mid-air collisions (use of ACAS)).

[63] Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91, OJ L 212, 22.8.2018, p. 1-122 (available at https://www.easa.europa.eu/document-library/regulations#basic-regulation).

[64] The EASCG is a joint coordination and advisory group, which was established to coordinate the ATM-related standardisation activities, essentially stemming from the Master Plan. More information and the RDP can be found on the EASCG website (https://www.eascg.eu/).

[65] The EUSCG is a joint coordination and advisory group established to coordinate the UAS-related standardisation activities across Europe, essentially stemming from the EU regulations and EASA rule-making initiatives. The EUSCG provides a link between the European activities and those at international level. More information and the RDP can be found on the EUSCG website (https://www.eascg.eu/).

[66] See: https://www.eurocae.net/about-us/ecscg/

[67] https://www.easa.europa.eu/document-library/general-publications/european-plan-aviation-safety-2019-2023

FIGURE 29. STANDARDS AND REGULATORY NEEDS

	No additional needs identified in R&D
	Standardisation need identified in R&D
	Standardisation/Regulatory work planned or ongoing
<blank>	Analysis in R&D pending
EASA EPAS	covered in EPAS
EASCG	covered in EASCG Rolling Development Plan
EUSCG	covered in EUSCG Rolling Development Plan

Essential operational change:	CNS infrastructure and services				
Deployment scenario	**Solution code**	**Solution name**	**Standards**	**Regulations**	**covered in...**
CNS rationalisation	#109	Air traffic service datalink using satcom class B			EASCG
	#110	ADS-B surveillance of aircraft in flight and on the surface			EASCG
	#103	LPV approaches using SBAS as alternative to ILS CAT I			
	#55	Precision approaches using GBAS CAT II/III			EASCG
Enhanced airborne collision avoidance for commercial air transport normal operations (ACAS Xa)	PJ.11-A1	Enhanced airborne collision avoidance for commercial air transport normal operations (ACAS Xa)			EASA EPAS, EASCG
Alternative position, navigation and timing (A-PNT) - short term	PJ.14-03-04	RNP-1 reversion based on DME-DME			EASCG
CNS services evolution	PJ.14-W2-76	Integrated CNS and spectrum			
	PJ.14-W2-77	FCI services			
	PJ.14-W2-60	FCI terrestrial data link and A-PNT enabler (L-DACS)			
	PJ.14-W2-107	Future satellite communications data link			EASCG
	PJ.14-W2-79	Dual frequency / multi constellation (DFMC) GNSS/SBAS and GBAS			EASCG
	PJ.14-W2-81	Long term alternative position, navigation and timing (A-PNT)			
Hyper-connected ATM	PJ.14-W2-61	Hyper-connected ATM			

Essential operational change:	ATM interconnected network				
Deployment scenario	**Solution code**	**Solution name**	**Standards**	**Regulations**	**covered in...**
Enhanced ATFM slot swapping	#56	Enhanced ATFM slot swapping			
Airport integration into the network	#61	CWP airport - low cost and simple departure data entry panel			
Collaborative airport (airport operations plan - network operations plan, phase 2)	#21	Airport operations plan and AOP-NOP seamless integration			
SWIM TI (technical infrastructure) purple profile for air/ground advisory information sharing	PJ.17-01	SWIM TI purple profile for air/ground advisory information sharing			EASCG
SWIM TI purple profile for air/ground safety-critical information sharing	PJ.17-W2-100	SWIM TI purple profile for air/ground safety-critical information sharing			
Enhanced network traffic prediction and shared complexity representation	PJ.09-W2-45	Enhanced network traffic prediction and shared complexity representation			
Network optimisation of multiple ATFCM time-based measures	PJ.09-W2-47	Network optimisation of multiple ATFCM time-based measures			
Collaborative network performance management	PJ.09-W2-49	Collaborative network performance management			
Digital collaborative airport performance management	PJ.04-W2-29	Digital collaborative airport performance management			
Collaborative framework for managing delay constraints on arrivals	PJ.07-W2-39	Collaborative framework for managing delay constraints on arrivals			
SWIM TI green profile for ground/ground civil military information sharing	PJ.17-W2-101	SWIM TI green profile for G/G civil military information sharing			
Enhanced collaborative airport performance planning and monitoring	PJ.04-W2-28	Enhanced collaborative airport performance planning and monitoring			
Digital integrated network management and ATC planning	PJ.09-W2-48	Digital integrated network management and ATC planning (INAP)			

Essential operational change:	Digital AIM and MET services				
Deployment scenario	**Solution code**	**Solution name**	**Standards**	**Regulations**	**covered in...**
Digitally enhanced briefing	#34	Digital integrated briefing			
Improved aviation AIM and MET services through automation and digitalisation	PJ.18-04a	Aeronautical information management (AIM) information			
	PJ.18-04b	Meteorological (MET) information			
Aircraft as an AIM/MET sensor and consumer	PJ.14-W2-110	Aircraft as an AIM/MET sensor and consumer			

Essential operational change:	U-space services				
Deployment scenario	Solution code	Solution name	Standards	Regulations	covered in...
U-space U1 — foundation services	U1S-01	e-Registration service			EASA EPAS
	U1S-02	e-Identification service			EASA EPAS
	U1S-03	Pre-tactical geo-fencing service			
U-space U2 — initial services	U2S-01	Tactical geo-fencing service			
	U2S-02	Emergency management service			
	U2S-03	Strategic de-confliction service			
	U2S-04	Weather information service			
	U2S-05	Tracking service			
	U2S-06	Flight planning management service			
	U2S-07	Monitoring service			
	U2S-08	Traffic information service			
	U2S-09	Drone aeronautical information management service			
	U2S-10	Procedural Interface with ATC service			
U-space U3 — advanced services	U3S-01	Dynamic geo-fencing service			
	U3S-02	Tactical de-confliction service			
	U3S-03	Collaborative interface with ATC service			
	U3S-04	Dynamic capacity management service			

Essential operational change:	Virtualisation of service provision				
Deployment scenario	Solution code	Solution name	Standards	Regulations	covered in...
Remotely provided ATS for multiple aerodromes	PJ.05-02	Multiple remote tower module			EASA EPAS
Virtual centre concept	PJ.16-03	Enabling rationalisation of infrastructure using virtual centre based technology			
Multiple remote towers and remote tower centre	PJ.05-W2-35	Multiple remote towers and remote tower centre			EASA EPAS
HMI interaction modes for ATC centres and airport towers	PJ.05-W2-97	HMI interaction modes for airport tower			
	PJ.10-W2-96	HMI interaction modes for ATC centre			
Delegation of services amongst ATSUs	PJ.10-W2-93	Delegation of services amongst ATSUs			

Essential operational change:	Airport and TMA performance				
Deployment scenario	Solution code	Solution name	Standards	Regulations	covered in...
Enhanced airport safety nets	#01	Runway status lights			
Airport safety nets vehicle	#04	Enhanced traffic situational awareness and airport safety nets for the vehicle drivers			
Integrated surface management	#47	Guidance assistance through airfield ground lighting			
Enhanced AMAN/DMAN integration	#54	Flow-based integration of arrival and departure management			
Efficient aircraft separation during take-off and final approach	PJ.02-01	Wake turbulence separation optimization			
	PJ.02-03	Minimum-pair separations based on RSP			
Enhanced arrival procedures	PJ.02-02	Enhanced arrival procedures			
Enhanced visual operations	PJ.03a-04	Enhanced visual operations			
Traffic optimisation on single- and multiple-runway airports	PJ.02-08	Traffic optimisation on single- and multiple-runway airports			
Traffic alerts for pilots for airport operations	PJ.03b-05	Traffic alerts for pilots for airport operations			EASA EPAS
Dynamic extended TMAs for advanced CCO/CDO and improved arrival and departure operations	PJ.01-W2-08	Dynamic E-TMA for advanced continuous climb and descent operations and improved arrival and departure			
Digital evolution of integrated surface management	PJ.02-W2-21	Digital evolution of integrated surface management			EASA EPAS
Next generation AMAN for a 4D environment	PJ.01-W2-02	Next generation AMAN for a 4D environment			
Advanced geometric GNSS-based procedures in TMAs	PJ.02-W2-04	Advanced geometric GNSS-based procedures in TMAs			
Evolution of separation minima for increased runway throughput	PJ.02-W2-14	Evolution of separation minima for increased runway throughput			

Essential operational change:	Fully dynamic and optimised airspace				
Deployment scenario	Solution code	Solution name	Standards	Regulations	covered in...
High-productivity controller team organisation	PJ.10-01a	High-productivity controller team organisation			
Flight-centric ATC and improved distribution of separation responsibility in ATC	PJ.10-W2-73	Flight-centric ATC and improved distribution of separation responsibility in ATC			EASA EPAS
Dynamic airspace configuration	PJ.09-W2-44	Dynamic airspace configurations (DAC)			
Mission trajectories management with integrated dynamic mobile areas type 1 and type 2	PJ.07-W2-40	Mission trajectories management with integrated dynamic mobile areas type 1 and type 2			

Essential operational change:	Trajectory-based operations				
Deployment scenario	Solution code	Solution name	Standards	Regulations	covered in...
Enhanced safety nets	#60	Enhanced short-term conflict alert (STCA) for terminal manoeuvring areas (TMAs)			
	#69	Enhanced STCA with down-linked parameters			
eFPL supporting SBT transition to RBT	PJ.18-02c	eFPL supporting SBT transition to RBT			
Improved ground trajectory predictions enabling future automation tools	PJ.18-W2-53	Improved ground trajectory predictions enabling future automation tools			
RBT revision supported by datalink and increased automation	PJ.18-W2-57	RBT revision supported by datalink and increased automation			
Enhanced integration of AU trajectory definition and network management processes	PJ.07-W2-38	Enhanced integration of AU trajectory definition and network management processes			
Improved vertical profiles through enhanced vertical clearances	PJ.18-W2-56	Improved vertical profiles through enhanced vertical clearances			

Essential operational change:	Multimodal mobility and integration of all airspace users				
Deployment scenario	Solution code	Solution name	Standards	Regulations	covered in...
Optimised low-level IFR routes for rotorcraft	#113	Optimised low-level IFR routes for rotorcraft			
Independent rotorcraft operations at airports	PJ.02-05	Independent rotorcraft operations at the airports			EASA EPAS
Enhanced rotorcraft and GA operations in the TMA	PJ.01-06	Enhanced rotorcraft and GA operations in the TMA			EASA EPAS
Collision avoidance for IFR RPAS	PJ.13-W2-111	Collision avoidance for IFR RPAS			EASA EPAS
IFR RPAS accommodation in airspace classes A to C	PJ.13-W2-115	IFR RPAS accommodation in airspace classes A to C			EASA EPAS
IFR RPAS integration in airspace classes A to C	PJ.13-W2-117	IFR RPAS integration in airspace classes A to C			EASA EPAS

BUSINESS VIEW

This chapter provides a business view of the monetised benefits and investment costs associated with the deployment of the full Master Plan vision, namely phases A to D (see Chapter 2).
Section 6.1 provides a holistic view of the benefits and costs of the deployment of (and investments required in) the SESAR project for manned aviation. Section 6.2 does the same for the SESAR project for unmanned aviation. Section 6.3 covers the topic of incentives, looking at both the current options and possible future alternatives.

6.1 HOLISTIC VIEW OF SESAR NET BENEFITS FOR MANNED AVIATION

Realising the vision will not only bring significant direct performance gains to ATM and aviation, it will also benefit the European economy and society in general.

This section provides an estimation of the net holistic benefits of the deployment of that part of the vision that covers conventional ATM — that is, excluding drones — thus allowing traceability against the business view developed in the 2015 edition of the Master Plan. Net gains are computed by estimating both the benefits associated with the deployment of the SESAR vision and the associated deployment costs (investments). Gains resulting from unmanned aviation are covered in Section 6.2.

Achieving these benefits will require harnessing of SESAR capabilities as well as other enablers, such as the regulatory framework and ATM architecture. The business view builds on the assumption that necessary changes will materialise and that SESAR Solutions will be put into operation in an optimal, timely, coordinated and synchronised manner, for example that the new air-ground voice communication systems will be able to address the challenges arising from flight-centric and flow-centric operations, or that a regulatory framework may need to be developed to enable DAC.

The holistic perspective has been calculated for both of the individual high-level options for rolling out SESAR, as described in Section 5.1. The timely materialisation of the full gain from option 1 is linked to the implementation of several additional requirements as described in Section 5.1.

The figures in this business view for investment levels and performance gains represent totals across the ECAC region. Investments do not include R&D costs but refer to the cost of deploying SESAR Solutions for the various stakeholders.

6.1.1 Holistic view on investment

Estimating realistic high-level figures for the investment levels is challenging, as many of the SESAR Solutions are still in the early stages of R&D, and SESAR Solutions for phase D are not yet in R&D. To address this uncertainty, numerous industry experts from across the whole ATM and aviation value chain have provided their insights.

To capture this inherent risk, a series of level ranges for investment have been defined. Following on from the median value proposed by various experts, a range of minimum and maximum values are derived. Unless otherwise specified, values provided for investments are the median and refer to option 1, which will be presented in the following paragraphs.

In addition to the values envelope, the investment levels have also been calculated for two distinct high-level options (see Section 5.1) for rolling out SESAR.

- **Option 1 — Deployment of the full vision by 2040:** total cumulative investment is estimated to be between EUR 23 billion and EUR 51 billion over the period 2012-2040, of which almost 90 % will be invested by 2035, the median expectation being in the order of EUR 37 billion.
- **Option 2 — Deployment of the full vision by 2050:** total cumulative investment fluctuates between EUR 25 billion and EUR 53 billion over the period 2012-2050, of which about 80 % is invested by 2035. The median level of investment is around EUR 39 billion.

FIGURE 30 presents the uncertainty in the assessment of investments needs. For SESAR 1 PCP and non-PCP solutions, there is reasonable certainty about the budgetary needs. As we enter the period where most of the SESAR 2020 solutions are expected to be deployed, the uncertainty grows.

The values proposed above consist of the cost of deploying SESAR from phases A to D for manned aviation: scheduled airlines, business aviation, general

FIGURE 30. **TOTAL CUMULATIVE INVESTMENTS FOR DELIVERING THE SESAR VISION — MANNED AVIATION**

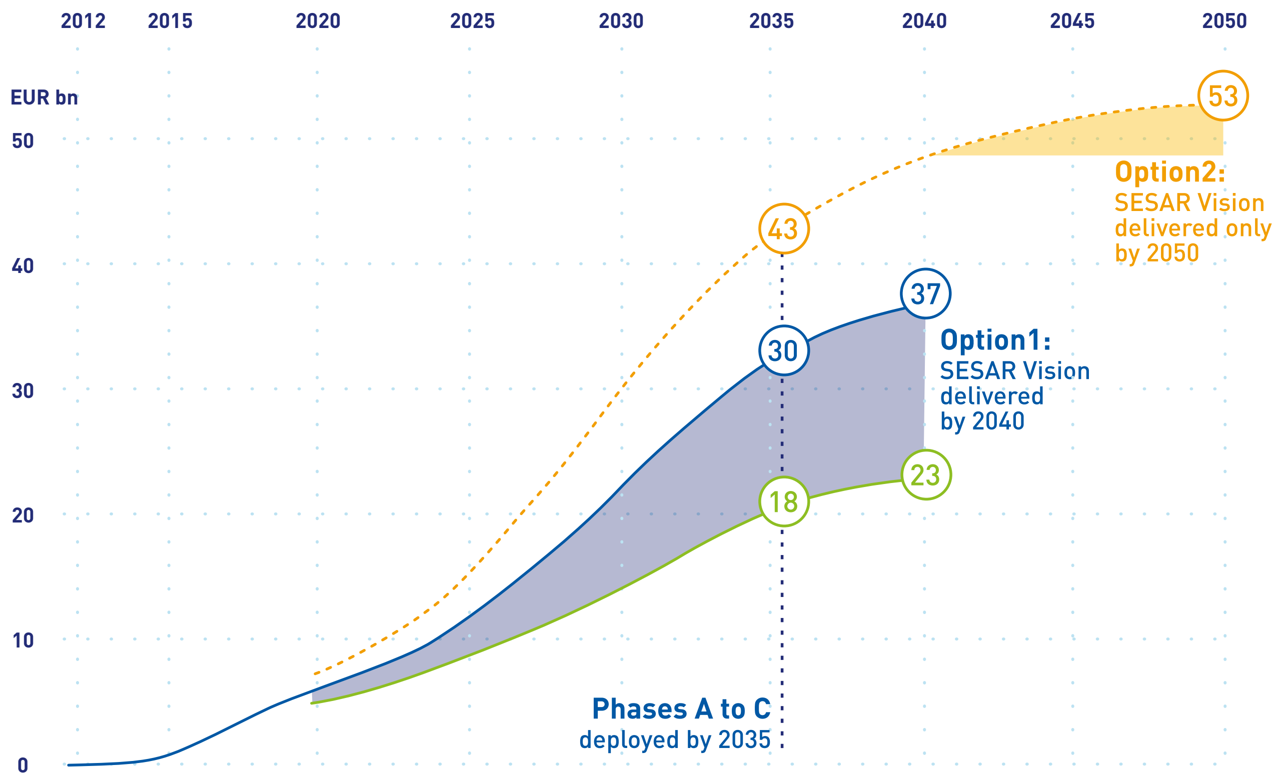
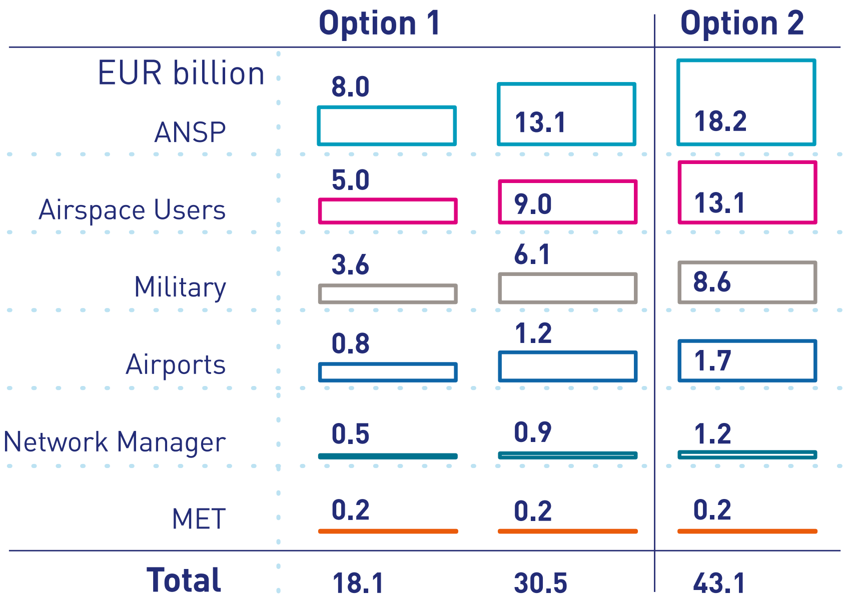


FIGURE 31. **TOTAL CUMULATIVE INVESTMENTS BY STAKEHOLDER FOR SESAR PHASES A TO C — MANNED AVIATION (BILLION EUR)**



aviation, rotorcraft, ANSPs ([68]), the Network Manager, airports and the military ([69]).

A closer look at the values provided offers an approximate picture of the investment levels considered in the business view for phases A to C, broken down by stakeholder (**FIGURE 31**).

- **ANSPs** expect to invest in the order of EUR 13.1 billion, with a considerable level of uncertainty because of the anticipated need to adapt to the future paradigm of TBO and virtualisation.

- **Airspace users**, including scheduled airlines, business aviation, general aviation and rotorcraft, predict investments of around EUR 9.0 billion. Most of their upgrades are expected in phases B and C, adding more uncertainty to the cost assessment.

- **The military** has applied a top-down approach to estimating its costs, which are in the region of EUR 6.1 billion.

- Investments by **airports**, the **Network Manager** and **MET providers** are of a smaller order of magnitude, as expected.

6.1.2 Holistic view on benefits

While Chapter 3 sets out the overall performance ambition for the 2035 horizon, this subsection provides a view on the benefits of SESAR for the 2050 horizon. The benefits are expressed as the difference in performance between the reference scenario (see Chapter 3) and the SESAR vision to 2050.

The holistic benefits are based on three quantified types of impact.

- **Direct impact on the value chain.** This includes the total gross domestic product (GDP) created by SESAR along the direct value chain (ATM equipment manufacturers, aircraft manufacturers, the military ([70]), airspace users, ANSPs ([71]) and airports). The assessment quantifies value created through additional activity enabled by SESAR (both through increased capacity

([68]) The civil ANSP investment assessment does not include investment costs for remote towers for small airports because deployment depends on very local decisions. Furthermore, it has been assumed that some key regional virtual centres (i.e. nine functional airspace blocks) will require the highest investment costs.

([69]) The military investment assessment does not include non-SESAR SES airborne equipage costs stemming from specific SES regulations such as PBN, surveillance performance and interoperability, voice communications systems and datalink services.

([70]) While the military is one of the actors with a direct economic impact, this impact has been limited to industry manufacturers producing military products (aircraft and/or avionics) because limited information is available on the quantitative connection of the military to direct GDP.

([71]) This subsection includes the Network Manager among the ANSPs.

and investments linked to the various solutions). The direct impact considers cost savings for the industry (cost efficiency leading to lower ANS unit costs per flight, operational efficiency and environmental efficiency). It also takes into account that SESAR Solutions that have safety as a primary objective have implications for costs and benefits that are not monetised.

- **Indirect impact of the value chain.**

  On suppliers. This includes the total GDP created by the increased activity of those supplying the direct value chain. It includes, for example, the GDP created by airline suppliers, following the direct impact on airlines described above.

  Passenger benefits and other impacts on society. This includes the quantified impact on passengers and society, driven by SESAR. Passengers benefit from additional flights enabled and time savings (because of minimised delays and shorter flights). Other quantified SESAR impacts are lower air pollution and climate change impact per flight (driven by lower fuel burn).

In addition, multiple non-quantified benefits can be expected as SESAR is implemented.

- **Noise reduction:** as described in Subsection 3.2.4, SESAR Solutions provide and/or enable new procedures, for example CCO/CDO and curved approaches or noise preferential routes supported by RNP and/or GBAS. These should not be excluded from environmental assessments of SESAR Solutions.

- **Industrial leadership** in ATM and aviation being at the forefront of innovation.

- **A highly competitive European aviation industry** in the global aviation landscape.

- **Increased mobility** with a **lower environmental impact**.

- **High standards in terms of safety, security and social standards.**

- **Indirect time savings for passengers,** for example driven by increased predictability of flights.

Benefit levels are calculated for two distinct high-level options. Option 1 has two distinct advantages over option 2, described below (see also Section 5.1).

It would **reach the targeted full vision earlier** by taking rationalisation opportunities for investments.

This option would also **increase robustness regarding uncertainty through a more scalable system**. Indeed, while long-term traffic trends indicate robust traffic growth, experience also shows that these trends can be affected or disrupted momentarily because of unpredictable events such as economic crises or political decisions. It is therefore essential to build a system that will be able not only to accommodate planned traffic growth but also to react to unplanned and speculative traffic fluctuations with agility and adaptability.

The results below are expressed as a range, highlighting the difference in impact between options 1 and 2.

Yearly benefits will amount to EUR 50 billion (both options) in 2035 and EUR 55 billion (option 2) to EUR 64 billion (option 1) in 2040, with an indicative split as follows (**FIGURE 32**) [72].

- **Direct impact on the value chain:** EUR 19 billion in 2035 (both options) and EUR 19 billion (option 2) to EUR 22 billion (option 1) in 2040, driven mostly by cost savings of EUR 14 billion in 2035 (both options) and EUR 15 billion (option 2) to EUR 16 billion (option 1) in 2040.

- **Indirect impact on suppliers in the value chain:** EUR 6 billion in 2035 (both options) and EUR 6 billion (option 2) to EUR 8 billion (option 1) in 2040.

- **Indirect impact on society, including passenger benefits:** EUR 25 billion in 2035 (both options) and EUR 30 billion (option 2) to EUR 34 billion (option 1) in 2040, driven mainly by two factors. First, the benefits to passengers from passenger time savings enabled by SESAR are EUR 14 billion in 2035 (both options) and EUR 15 billion (option 2) to EUR 18 billion (option 1) in 2040. Second, the benefits of flights enabled by SESAR are EUR 11 billion in 2035 (both options) and EUR 16 billion (option 2) to EUR 17 billion (option 1) in 2040.

[72] Any slight anomalies are due to rounding.

FIGURE 32. **BREAKDOWN OF YEARLY BENEFITS IN 2035 AND 2040 (BOTH OPTIONS) — MANNED AVIATION**

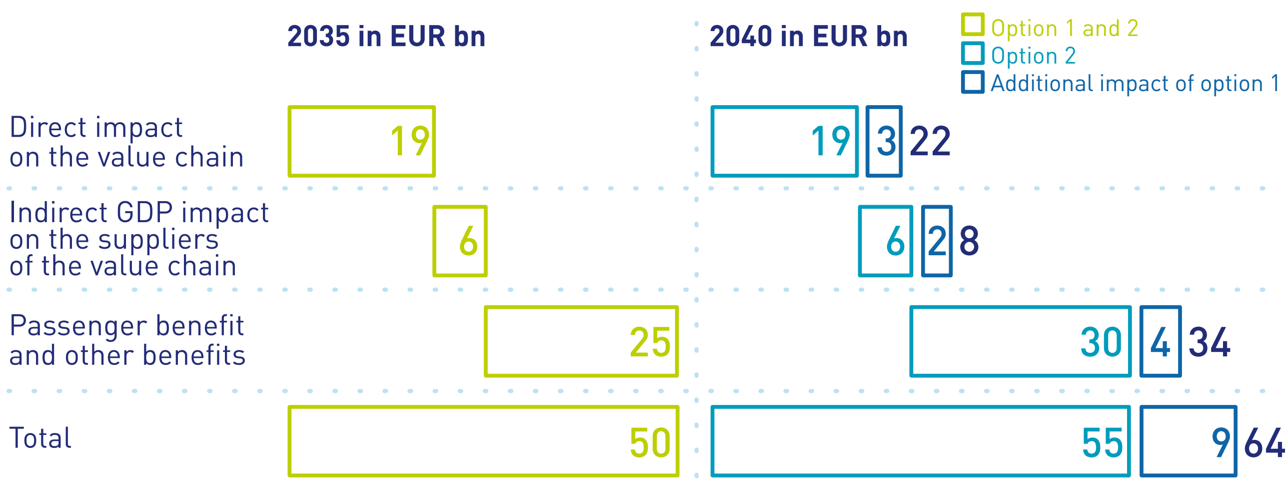
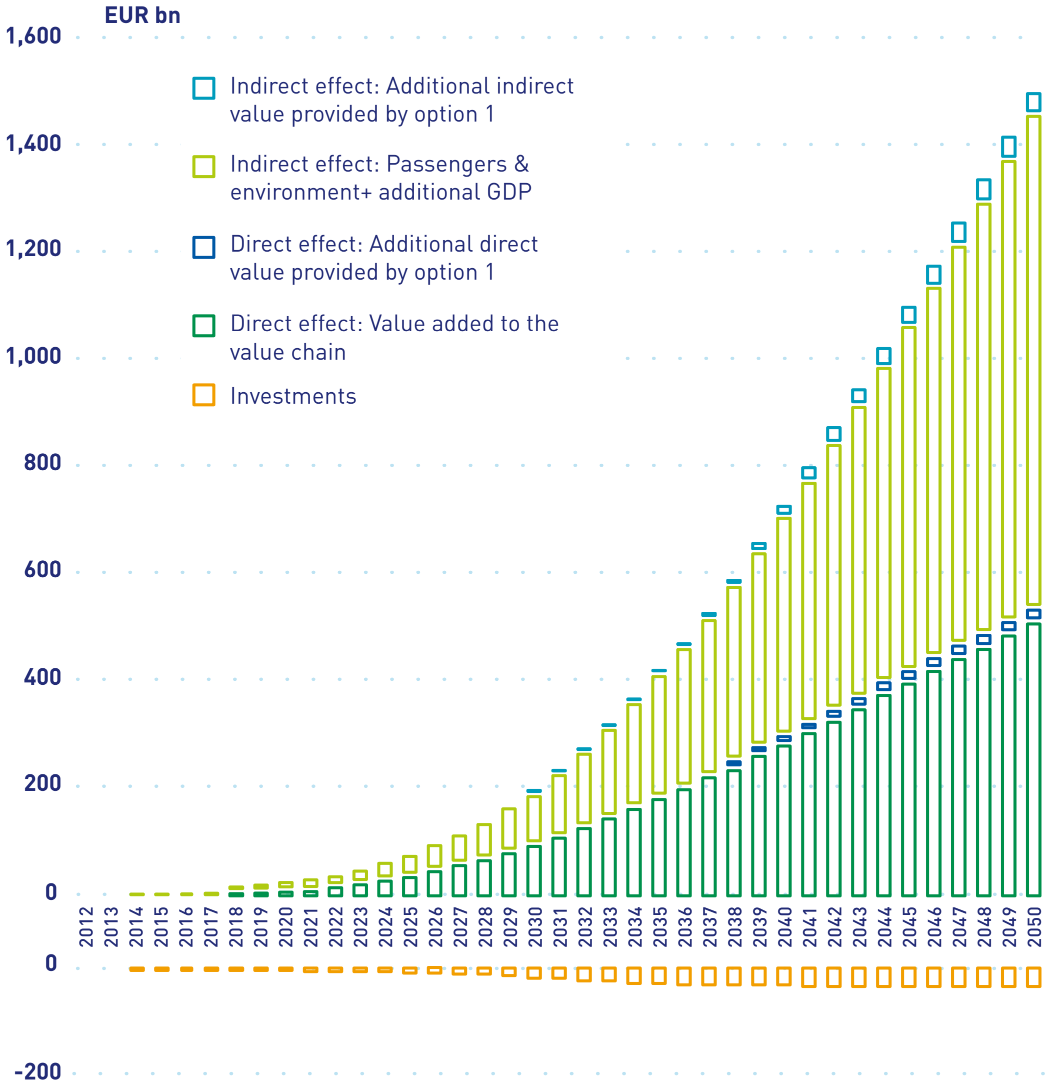


FIGURE 33. SESAR DELIVERS SIGNIFICANT VALUE FOR EUROPE (UNDISCOUNTED)



6.1.3 Net result of the holistic view

FIGURE 33 shows that SESAR delivers substantial value for Europe with required investments amounting to only between 2 % and 4 % of the overall expected benefits.

Performance benefits and the magnitude of expected gains rapidly outgrow investments. **FIGURE 33** also shows the additional value brought by option 1 compared with option 2 (the blue shading in the bars).

The difference in deployment pace between the two options, together with the EUR 2 billion difference in overall investment levels and the cumulative EUR 59 billion from higher annual performance gains, means that option 1 brings a EUR 7 billion higher overall benefit in net present value (NPV) compared with option 2.

There is a EUR 7 billion NPV advantage of option 1 over option 2; however, there is still a strong need to ensure support for option 1 and to call on all relevant stakeholders to commit to:

- a new way of working within SESAR, building on agility, openness and coordination;
- establishing regulations that promote innovation, service orientation and building on appropriate market take-up incentive mechanisms.

6.2 HOLISTIC VIEW OF SESAR NET BENEFITS FOR DRONES

This section provides an estimate of the investments required to support the safe and efficient deployment of drones [73] in Europe, in addition to the benefits expected to arise from this future drone ecosystem. Both benefits and investment levels are covered in detail, with the benefits largely drawn from the previously released 2016 *Drones outlook study* [74].

European demand within the drone marketplace is valued at in excess of EUR 10 billion annually [75], in nominal terms, leading to a cumulative benefit of over EUR 140 billion by 2035 [76]. Civil missions for government purposes and commercial businesses are expected to generate the majority of this value on the basis of multibillion product and service industries. The defence and leisure industries will continue to contribute to this marketplace and remain a source of high value in the short term, representing together nearly EUR 2 billion in annual product-related turnover for the industry in the long term [77].

The minimum infrastructure investment required to ensure safety and unlock the value at stake for Europe is attainable through relatively low investments, leveraging existing infrastructure and scaling up through investments in automated and smart systems.

[73] In line with the *Drones outlook study and drone roadmap, this document uses the term 'drones' as a generic term to cover all types of UAS , be they remotely piloted (RPAS) or automated. As an exception, the term 'RPAS' may be used when a specific aspect of such vehicles (the fact that they are operated by a pilot instead of being automated) is addressed.*

[74] The 2016 *Drone outlook study can be found on the SESAR website:* https://www.sesarju.eu/sites/default/files/documents/reports/European_Drones_Outlook_Study_2016.pdf

[75] 2016 *Drones outlook study, Section 4.2 on urban air mobility addition.*

[76] Composed of commercial, government and leisure drones (excluding defence).

[77] Although the 2016 *Drones outlook study assessed the economic impact for defence, as noted above, these figures have been excluded from the overall benefits presented in this document, as limited data were available on the investment needs, and therefore presenting the full benefits without the full anticipated investments was deemed misleading.*

The assessment has identified key investments by stakeholders amounting to nearly EUR 4.5 billion by 2035 (**FIGURE 34**).

The investment in U-space should be viewed as critical to unlocking the future potential benefits from the drone ecosystem, accounting for > 85 % of the anticipated benefit by 2035.

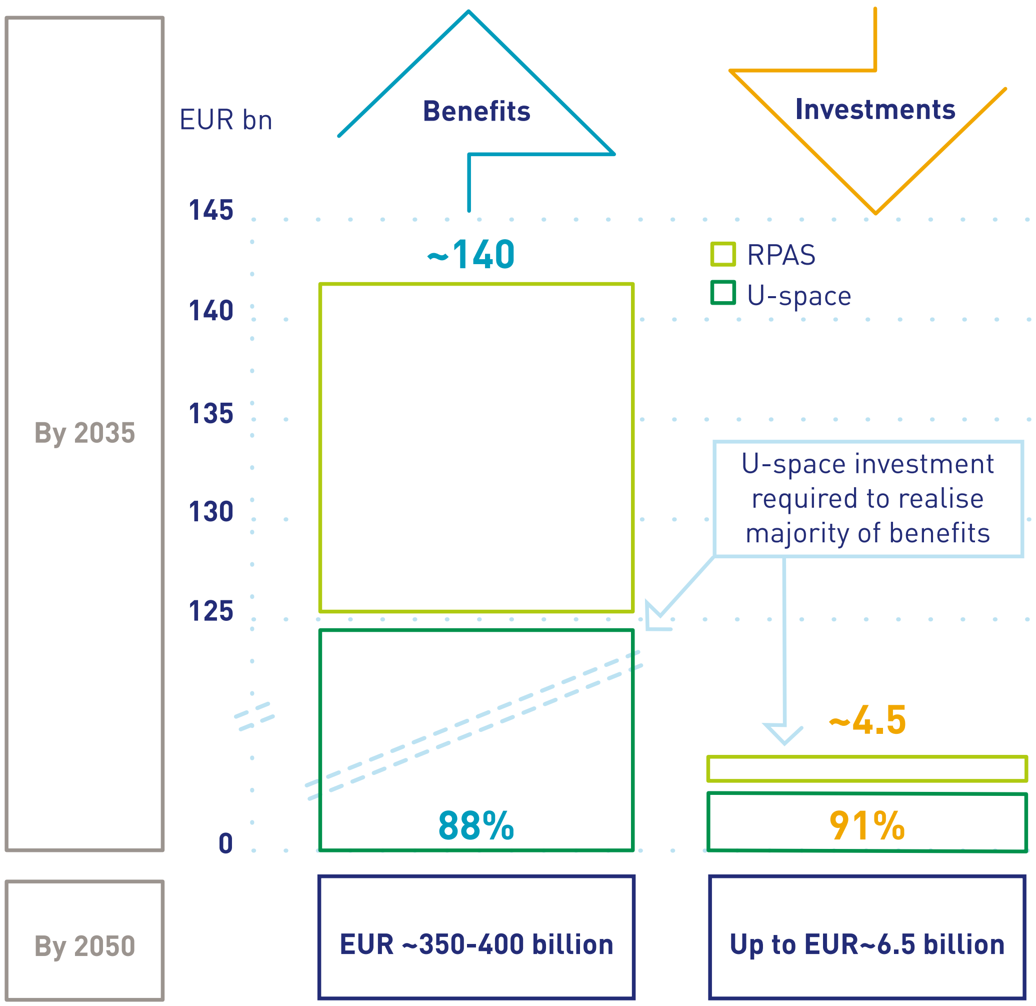
6.2.1 Holistic view on investments

This assessment aims to identify the investments related to ATM required for the safe and efficient integration of drones into European airspace. The figures are based on a number of assumptions that carry significant uncertainty. As a result, the overall investment figures should be interpreted in terms of their order of magnitude only.

The anticipated investments have been organised in three categories: infrastructure and services, airborne investments and human resources. Investment levels associated with each category and subcategory are shown in **FIGURE 35**, in addition to a deployment view showing investments over time in **FIGURE 36**.

For each identified investment subcategory, a high-level assessment and assumption base were developed to provide a view on the potential investment level for

FIGURE 34. **OVERVIEW OF INVESTMENTS ASSOCIATED WITH THE SAFE INTEGRATION OF DRONES AND BENEFIT LEVELS**



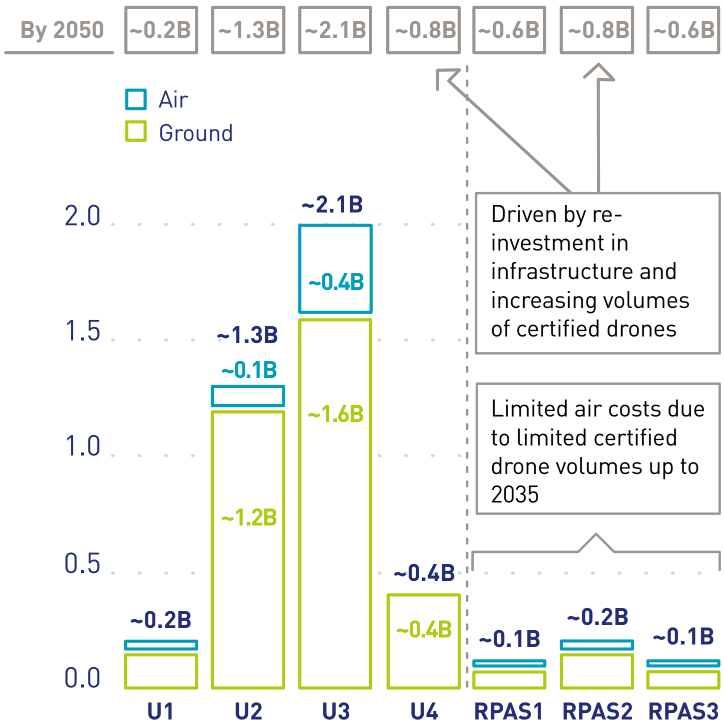
Sources: 2016 *Drones outlook study*, SESAR and stakeholder assessments.

NB: Investments cover only changes related to the safe integration of drones. In order to realise the benefits, additional investments that are not safety-related will have to be made by stakeholders, and these are not accounted for here (e.g. investments related to commercial service delivery).

FIGURE 35. BREAKDOWN OF INVESTMENT LEVEL BY CATEGORY AND ASSOCIATION WITH EACH PHASE

Investment category and sub category	Investment (2035)
Infrastructure & services	**~€ 3.4B**
ATC interface & airport adaptations	~€1.2B
Drone traffic management	~€0.9B
Protection of airports & sensitives sites	~€0.3B
Telecom & Satcom	~€0.6B
Geo-fencing database	~€0.1B
Enhanced data provision and info sharing	~€0.1B
Drone traffic management oversight	~€0.1B
e-registration and identification	~€0.1B
System hardware and software	**~€0.7B**
Drone systems	~€0.6B
On other aircraft	~€0.1B
Human resources	**~€0.4B**
Procedure development	~€0.3B
ATC personnel training	~€0.1B
Total	**~€4.5B**

~6.5B by 2050



NB: Investments associated with a particular phase, regardless of the point in time when the investment occurs (e.g. investments to support all U3 services, regardless of whether investment started in U2).

FIGURE 36. INVESTMENT NEEDS FOR DRONE DEPLOYMENT IN EUROPE (UNDISCOUNTED)

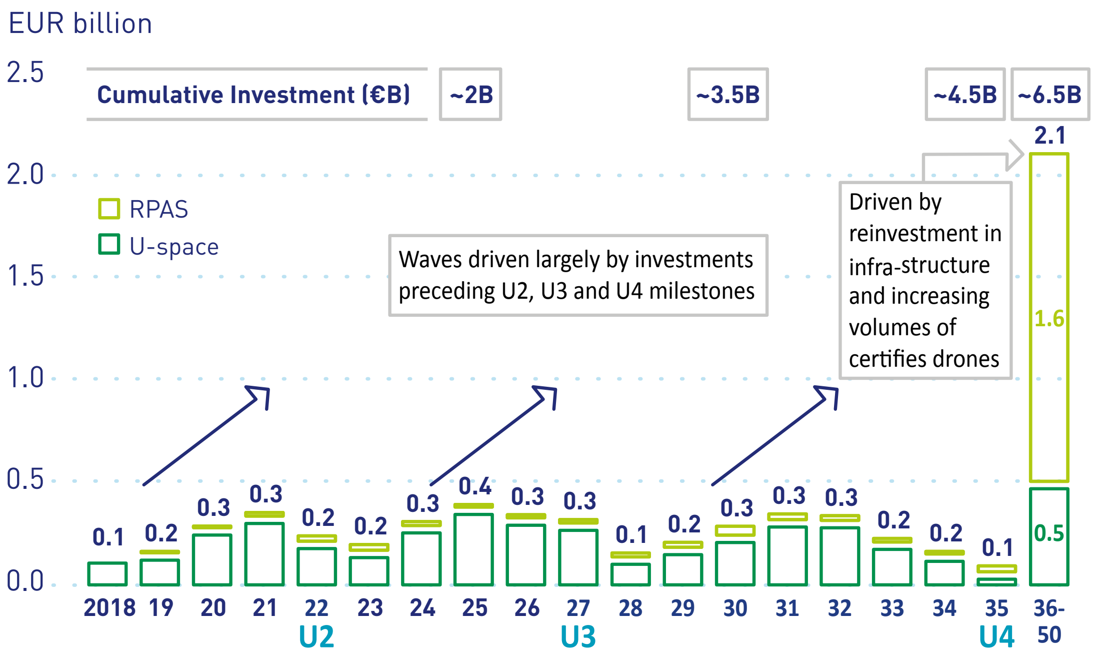
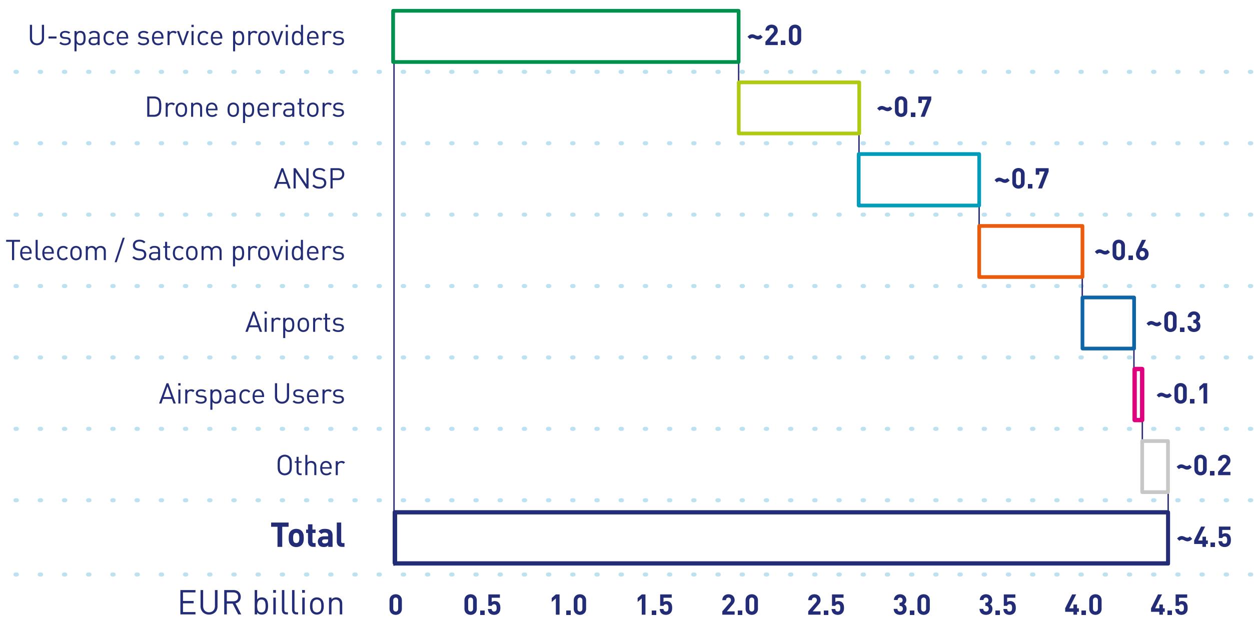


FIGURE 37. **PRELIMINARY STAKEHOLDER INVESTMENT BREAKDOWN FOR 2035**



stakeholders. The split between the assessment and associated stakeholder is expected to evolve as the drone ecosystem maturity level increases. To facilitate this exercise, primary, secondary and tertiary stakeholders were identified for each investment category and high-level assumptions drove a percentage split across the stakeholders. This assessment should not be interpreted as exhaustive or final but, rather, as a directional view to be further refined.

U-space service providers and drone operators are expected to invest the most across stakeholder groups ([78]). For U-space service providers, this is driven by the investments required to support new services in the ecosystem, while large investments by drone operators are required to ensure that the drones are appropriately equipped to enable the required services. The scale of operations and number of drones are expected to grow substantially, making the associated investment meaningful (the fleet size in this specific category will grow from under 10 000 drones in 2015 to nearly 400 000 in 2050). The military performs all the roles of the various stakeholders, namely airspace users, ANSPs, airport operators, regulators and drone operators. A standalone assessment of available military data indicates that partial investment levels are in the order of EUR 400 million ([79]).

Investment levels are assumed not to vary significantly between the two distinct high-level options (see Section 5.1) for rolling out SESAR, even though the slower evolution of the ATM system after 2035 might lead to a resulting lower investment amount under option 2.

6.2.2 Holistic view on benefits

An economic impact analysis of the entire value chain for each demand area revealed that the yearly potential for the European market would exceed EUR 10 billion by 2035 and would grow further to approximately EUR 15 billion by 2050, with agriculture expected to drive EUR 4 billion to EUR 5 billion of this market by 2035. A market of this size will also drive new job creation throughout all Member States, as each will need localised operations, pilots, maintenance contractors and insurers, among other specific occupations. In

([78]) It is expected that traditional airspace users should not incur major additional investments for the development of U-space.

([79]) Unit-level airborne investments for certified drones were used as a proxy and applied to the anticipated military drone fleet. Ground investments for airport adaptations and ATC interface requirements, were applied to 10 military air bases in Europe. Additional investments may be required and this assessment will be updated as more data become available.

short, over 100 000 jobs are expected to be generated directly by this significant market [80], in addition to many other indirect benefits.

In addition to the aforementioned benefits, the business assessment also takes into account benefits stemming from the growth and adoption of urban air mobility [81]. It is envisaged that this form of mobility will result in market value of at least EUR 2 billion annually by 2031, with market take-off in 2027 [82]. The value is calculated by estimating adoption across the following three use cases:

- city to airport travel — based on actual airport passengers and price-sensitivity analysis;
- taxi use — based on actual origin-destination figures, focusing on long-distance trunk routes;
- commuting — typically high-volume routes.

Volumes were determined by considering 25-30 European cities from an initial assessment based on the 130 largest cities worldwide.

Benefit levels have been assessed for the two distinct high-level options (see Section 5.1) for rolling out SESAR.

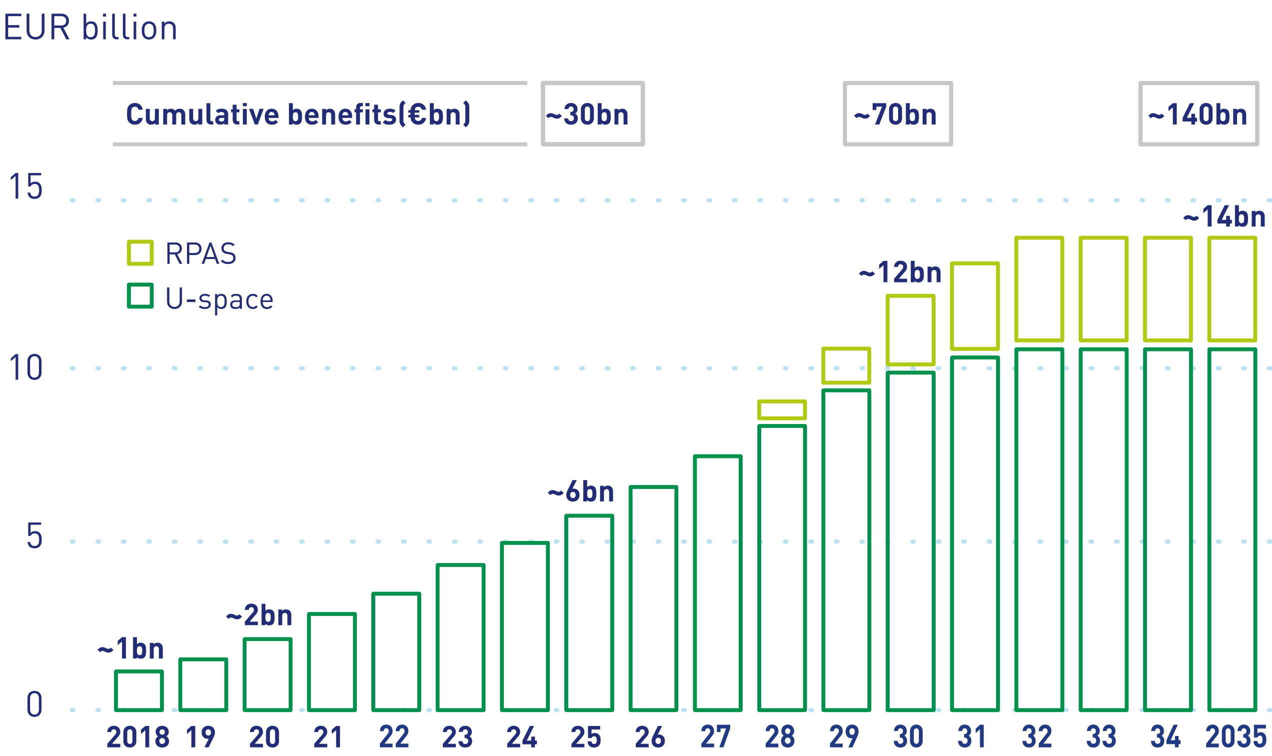
- **Option 1 — deployment of the full vision by 2040:** under option 1, it is assumed that the total value associated with drones could be unlocked, given that the required ATM system would be installed with the full vision, including phases A to D, achieved by 2040.
- **Option 2 — deployment of the full vision by 2050:** under option 2, it seems

[80] Based on data from the Organisation for Economic Cooperation and Development.

[81] Urban air mobility refers to an envisaged future state where people and/or goods can be transported around densely populated urban areas within very short time frames, leveraging airspace to do this.

[82] Urban air mobility figures based on an assessment performed by Boston Consulting Group in collaboration with Airbus.

FIGURE 38. **ECONOMIC BENEFITS OF DRONE DEPLOYMENT IN EUROPE (UNDISCOUNTED)**



Sources: 2016 *Drones Outlook Study*; urban air mobility input from external BCG project in collaboration with Airbus.

reasonable to assume that at least part of the drone value would not be unlocked, given the slower transition to the targeted ATM system.

The total annual economic value under option 1 across the indicated landscapes is summarised in **FIGURE 38**.

6.3 INCENTIVISATION STRATEGY

The existing SES framework already includes incentive schemes aimed at supporting the timely and synchronised deployment of technology. In particular:

- the existing SES regulations provide several mechanisms to incentivise deployment, including modulation of charges to support avionics equipage and different treatment of restructuring costs within the performance scheme;
- the common project legislation provides public funding via the relevant EU funding programmes, 'to encourage early investment from stakeholders and mitigate deployment aspects for which the cost-benefit analysis is less positive';
- the European Investment Bank has developed a range of financial instruments to support SESAR deployment.

However, within the scope the SESAR project seen as a whole, the scale of the

necessary transformation, the need to implement technologies as a result of existing or new mandates, and the need for synchronisation are much greater than are those for the individual ATM functionalities of common projects. For this reason, it was recommended in the context of the Airspace Architecture Study that the existing incentivisation framework be reviewed, also using the experience gained from the PCP, and that an overall incentivisation policy that would provide genuine incentives to early movers be developed and adopted.

Specific incentives should be offered to those stakeholders that implement the Master Plan or that shift towards innovative delivery models, with a focus on early movers, in order to initiate the transition.

It should be noted that further incentivisation needs may arise from new mandates such as the PBN and SPI regulations.

RISK MANAGEMENT

7.1 CAPTURING AND ANALYSING RISK

By looking at risk management, the Master Plan addresses the most significant risks associated with the delivery of the vision and the associated performance ambitions. Identifying risks does not imply that they will actually materialise; rather, it means that these risks have been identified and are to be adequately managed so that they do not affect the execution of the Master Plan.

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

As part of the 2019 Master Plan update campaign, a review of and update to 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 set out in the Master Plan. 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. More detailed action plans are incorporated in the SJU risk management framework and are regularly reported through the formal SJU reporting mechanisms.

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 implementation of SESAR as it is currently performed is not enough to address the airspace capacity challenge	Addressing the capacity challenge relies on the ability to make the entire European ATM system more scalable to evolving demand so that it is able to accommodate growing traffic while ensuring the highest levels of safety and acceptable delays This implies not only the implementation of relevant SESAR Solutions as identified in this Master Plan; this will need to be accompanied by improvements in airspace organisation and management smartly combined with minimal changes to the regulatory framework that will allow structural changes in the way ATM services are provided	Capacity performance ambition is not achieved leading to a significant increase in delays.	**By: Commission, SJU, SDM, NM, all stakeholders** **Actions** • Establish a strong and clear programme management supported by a robust implementation plan, a strong regulatory framework and mechanisms to reward early movers • Launch an EU-wide airspace reconfiguration programme in which the Member States, the Network Manager, ANSPs, civil airspace users and the military should work together to define and implement an optimal cross-FIR and flow-centric redesign of airspace sectors • Launch an EU-wide operational excellence programme in which the Network Manager, ANSPs, civil airspace users, the military and staff associations should work together to achieve operational harmonisation, aligning on air control centres' capacity and ways of working to best practices through systematic operational excellence throughout the network • Review policy options that, on their own or in addition to functional airspace blocks, could effectively deliver a virtual defragmentation of European skies and potentially generate higher levels of resilience by encouraging industry-based alliances to deliver core interoperability through common service delivery • Implement a certification and economic framework for ADSPs, taking into account possible restructuring of ANSP services as well as an EU framework for on-demand cross-border use of services (capacity on demand) • Continue to support the timely delivery of SESAR Solutions, contributing to the delivery of the proposed target architecture
2. Delays in the implementation of pre-SESAR prerequisites and common project functionalities	Some pre-SESAR prerequisites and some functionalities included in common project regulations may not be deployed as scheduled	• Delay in achieving the SESAR vision • Performance ambitions are not met as scheduled • Negative impact on the European economy, employment, mobility and the environment	**By: Commission, SDM, SJU, EUROCAE and all stakeholders** **Actions** • Synchronisation and coordination managed by SDM • Strong promotion of the deployment programme as well as other regulated or committed deployments • Delivery of an interoperability solution by 2020 and a supporting standard by 2021 • Ensure that incentives are designed to drive and support effective deployment

Risk	Description	Consequences/ impact	Mitigation actions
3. The inability to successfully develop and deploy the right solutions may threaten the safe integration of drones into the airspace	Although the SESAR programme includes solutions supporting the accommodation and integration of RPAS into the airspace, U-space U3/U4, that promises the highest value, this entails some challenges — such as operations of all categories of drones, including certified drones, operations in urban areas or high density of drone traffic — for which it remains uncertain that the necessary solutions will be delivered within the scheduled programme	• The economic and societal value at stake in relation to the development of the drone market are put at risk	**By: Commission, EASA, Member States regulator/ national supervisory authority** **Actions** • Commit additional R&D activities in support of U3/U4 • Accelerate the development of rules and means of compliance supporting harmonised deployment of U-space services across Europe
4. Unaddressed cybersecurity vulnerabilities may endanger future operations	Cybersecurity is a growing concern, especially as we are entering into the digital transformation of aviation. If these issues are not anticipated and well addressed, they may increase the ATM system's vulnerability to significant disruptions	• Increased possibility and/or impact of security breaches or potential cyber-threats stemming from intentional or unintentional acts and causing service disruption • Delays and potential higher costs during deployment and operations phases • Significant loss of public perception of the safety of air travel, leading eventually to a reduction in the economic value of aviation	**By: Commission, SJU, SDM, all stakeholders** **Actions** • Ensure efforts on ATM cybersecurity are coordinated, and assess policy options for strengthening cybersecurity and resilience • Continue to address cybersecurity during the development phase and as part of the validations conducted in the SESAR programme • Promote a security culture among all actors involved

Risk	Description	Consequences/ impact	Mitigation actions
5. Inability to accelerate the pace of solution development and deployment may put the European aviation community behind the demand curve	The digital European sky should be delivered in 2040. The current typical technology development life cycle of 15-20 years will not allow it to be ready for 2040, considering that work on some advanced topics is only just about to start, and the current complex and slow pace of the industrialisation phase including standardisation.	• Not being able to deliver changes fast enough will lead to the ATM system falling behind the demand curve, causing strong increases in delays and a significant loss in the economic value of aviation • The European ATM system and industry may lose its position at the forefront of worldwide aviation and ATM • Performance ambition is not met in time	**By: Commission, SJU, EASA, SDM, EUROCAE and all stakeholders** **Actions** • Secure funding for future research in the 2020+ timeframe • Implement a new way of working within SESAR, with more agility and increased collaboration between 'traditional' engineering domains and new entrants, with the objective of reducing the deployment life cycle to as close as possible to 5-10 years • Strengthen cooperation with standardisation bodies and reinforce relations with regulatory authorities in the development phase to prepare for deployment. • Support the evolution of the regulatory framework from a focus on operations and technology to a focus on effective delivery of future services, putting emphasis on what services (definition and baselining of services) should be provided and how (attached service level requirements as well as charging principles), rather than on what technologies should be implemented • Review the incentivisation policy to reward actors who are the first to implement the innovative solutions, supporting the move towards the achievement of the vision
6. Failure to manage human performance issues properly (human factors, competency and change management) in the development and implementation of the target concept	The digital transformation of aviation (especially the increased level of automation) along with the evolution of the service delivery models include some changes in the roles and responsibilities of the human The human performance issues include: • lack of appropriate competency, or a regulatory certification, training and assessment framework; • lack of verified and competent human resources to support operations in a new technological environment (in a timely manner 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)	• The digital European sky and its associated performance ambitions may not be achieved (on time) reducing the value of aviation for society. • There is also a risk of additional safety hazards	**By: SJU, Commission and all stakeholders** **Actions** • Continue to involve operational staff in the development of new concepts as well as R&D validation activities • Monitor all SESAR-oriented R&D and validation phases regarding human performance standards, methods and requirements • Ensure appropriate coordination between all stakeholders concerned to ensure consistency between initiatives related to human factors, competency and social dialogue • Commission to launch a human assessment of the changes resulting from the SES

Risk	Description	Consequences/ impact	Mitigation actions
7. Failure to coordinate successfully with other regions on harmonisation objectives	Harmonisation on interoperability needs at global level is crucial for worldwide seamless operations. It relies on the synchronised application of standards and common principles, which may come from ICAO provisions together with common technical and operational solutions for relevant aircraft and ATM systems. This also includes interoperability between civil and military actors, whether acting as airspace users or service providers	• The European modernisation programme is not aligned with other global plans • European products and services may not be usable in other parts of the world • Lack of consideration of common standards may cause additional work, resulting in delays in deployment and increased development costs • A basis for sound investment decision-making is not established • Adverse impact on national and collective defence capabilities	**By: Commission, SJU, Eurocontrol, EDA, SDM** **Actions** • Work towards global interoperability in the framework of ICAO working arrangements (especially on the GANP) • Continue to strengthen SESAR/NextGen coordination under the EU/US memorandum of cooperation and further develop additional collaboration with other global partners • Military to continue association with SES from the outset, and with the ICAO's work

ANNEXES

ANNEX A.

ESSENTIAL OPERATIONAL CHANGES WITH MAPPED DEPLOYMENT SCENARIOS/SOLUTIONS AND R&D ACTIVITIES

This annex contains a complete list of deployment scenarios and the related SESAR Solutions/activities for each EOC.

Key solutions/activities are those considered crucial to delivering the expected performance improvements and achieve the vision. Additional SESAR Solutions/activities are further topics that contribute to the EOC addressed in the SESAR programme.

EOC CNS infrastructure and services

PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
In deployment phase: key SESAR Solutions							
	CNS rationalisation	#109	Air traffic service datalink using satcom class B		B	Not applicable	Not applicable
		#110	ADS-B surveillance of aircraft in flight and on the surface		B	Not applicable	Not applicable
		#103	LPV approaches using SBAS as alternative to ILS CAT I		A	Not applicable	Not applicable
		#55	Precision approaches using GBAS CAT II/III		A	Not applicable	Not applicable
In development phase: Key Solutions approaching maturity							
	Enhanced airborne collision avoidance for commercial air transport normal operations (ACAS Xa)	PJ.11-A1	Enhanced airborne collision avoidance for commercial air transport normal operations (ACAS Xa)		B	Not applicable	Not applicable
	Alternative position, navigation and timing (A-PNT)- short term	PJ.14-03-04	RNP-1 reversion based on DME-DME		B	Not applicable	Not applicable
In development phase: Key R&D activities							
	CNS services evolution	PJ.14-W2-76	Integrated CNS and spectrum		C	PJ.14-01-01	CNS environment evolution
		PJ.14-W2-77	FCI services		C	PJ.14-02-04	FCI network technologies incl. voice solutions and military interfacing
		PJ.14-W2-60	FCI terrestrial data link and A-PNT enabler (L-DACS)		C	PJ.14-02-01	FCI terrestrial data link
		PJ.14-W2-107	Future satellite communications data link		C	PJ.14-02-02	Future satellite communications data link
		PJ.14-W2-79	Dual frequency / multi constellation (DFMC) GNSS/SBAS and GBAS		C	PJ.14-03-02 PJ.14-03-01	Multi constellation / multi frequency (MC/MF) GNSS GBAS
		PJ.14-W2-81	Long term alternative position, navigation and timing (A-PNT)		C	Not applicable	Not applicable
	Hyper-connected ATM	PJ.14-W2-61	Hyper-connected ATM		C	Not applicable	Not applicable
Additional SESAR Solutions in deployment							
	Aeronautical mobile airport communication system (AeroMACS)	#102	Aeronautical mobile airport communication system (AeroMACS)		A	Not applicable	Not applicable
	Cooperative surveillance ADS-B / WAM	#114	Cooperative surveillance ADS-B / WAM		B	Not applicable	Not applicable
Additional R&D activities in development							
	Completion of aeroMACS development	PJ.14-02-06	Completion of aeroMACS development		B	Not applicable	Not applicable
	ACAS evolution	PJ.11-A3	ACAS for commercial air transport specific operations – ACAS Xo		B	Not applicable	Not applicable
	Surveillance performance monitoring	PJ.14-W2-83	Surveillance performance monitoring		C	PJ.14-04-01	Surveillance performance monitoring
	New use and evolution of cooperative and non-cooperative surveillance	PJ.14-W2-84	New use and evolution of cooperative and non-cooperative surveillance		C	PJ.14-04-03	New use and evolution of cooperative and non-cooperative surveillance

EOC ATM interconnected network

PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
	In deployment phase: key SESAR Solutions						
✓	Initial SWIM: flight information exchange	#37	Extended flight plan		B	#67	AOC data increasing trajectory prediction accuracy
		PJ.18-02b	*Flight object interoperability (FO IOP)**		B	#28	Automated assistance to controller for seamless coordination, transfer and dialogue through improved trajectory data sharing
✓	Initial SWIM: SWIM infrastructure and profiles	#46	SWIM yellow profile		A	Not applicable	Not applicable
✓	Initial SWIM: meteorological information exchange	#35	MET information exchange		B	Not applicable	Not applicable
✓	Calculated take-off time to target time of arrival (TTA) for ATFCM purposes	#18	CTOT and TTA		A	Not applicable	Not applicable
✓	Collaborative NOP	#20	Collaborative NOP for step 1		A	Not applicable	Not applicable
		#21	Airport operations plan and AOP-NOP seamless integration **		B	Not applicable	Not applicable
✓	Automated support for traffic complexity assessment	#19	Automated support for traffic complexity detection and resolution		A	Not applicable	Not applicable
✓	Enhanced short-term ATFCM measures	#17	Advanced short-term ATFCM measures (STAM)		A	Not applicable	Not applicable
	Enhanced ATFM slot swapping	#56	Enhanced ATFM slot swapping		B	Not applicable	Not applicable
	Airport integration into the network	#61	CWP airport - low cost and simple departure data entry panel		A	Not applicable	Not applicable
	Collaborative airport (airport operations plan - network operations plan, phase 2)	#21	Airport operations plan and AOP-NOP seamless integration **		B	Not applicable	Not applicable
	In development phase: Key Solutions approaching maturity						
	SWIM TI (technical infrastructure) purple profile for air/ground advisory information sharing	PJ.17-01	SWIM TI purple profile for air/ground advisory information sharing		B	Not applicable	Not applicable
	In development phase: Key R&D activities						
	SWIM TI purple profile for air/ground safety-critical information sharing	PJ.17-W2-100	SWIM TI purple profile for air/ground safety-critical information sharing		C	PJ.17-07	SWIM TI purple profile for air/ground safety-critical information sharing
	Enhanced network traffic prediction and shared complexity representation	PJ.09-W2-45	Enhanced network traffic prediction and shared complexity representation		C	PJ.09-01 PJ.09-03	Network prediction and performance Collaborative network management functions
	Network optimisation of multiple ATFCM time-based measures	PJ.09-W2-47	Network optimisation of multiple ATFCM time-based measures		C	PJ.09-02 PJ.09-03	Integrated local DCB processes Collaborative network management functions
	Collaborative network performance management	PJ.09-W2-49	Collaborative network performance management		C	PJ.09-03	Collaborative network management functions
	Digital collaborative airport performance management	PJ.04-W2-29	Digital collaborative airport performance management		C	PJ.04-02	Enhanced collaborative airport performance management
	Collaborative framework for managing delay constraints on arrivals	PJ.07-W2-39	Collaborative framework for managing delay constraints on arrivals		C	PJ.07-02	AU fleet prioritization and preferences (UDPP)
	SWIM TI green profile for ground/ground civil military information sharing	PJ.17-W2-101	SWIM TI green profile for G/G civil military information sharing		C	PJ.17-03	SWIM TI green profile for G/G civil military information sharing
	Enhanced collaborative airport performance planning and monitoring	PJ.04-W2-28	Enhanced collaborative airport performance planning and monitoring		C	PJ.04-01	Enhanced collaborative airport performance planning and monitoring
	Digital integrated network management and ATC planning	PJ.09-W2-48	Digital integrated network management and ATC planning (INAP)		C	PJ.09-01 PJ.09-02	Network prediction and performance Integrated local DCB processes

EOC ATM interconnected network (continued)

PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
			Additional SESAR Solutions in deployment				
	UDPP departure	#57	UDPP departure		A	Not applicable	Not applicable
			Additional R&D activities in development				
	Sub-regional demand capacity balancing service	PJ.15-01	Sub-regional demand capacity balancing service		C	Not applicable	Not applicable
	SWIM-TI common runtime registry	PJ.17-08	SWIM-TI common runtime registry		C	Not applicable	Not applicable

**Solutions that are still in the pipeline for deployment but are part of PCP expected to be mature by the end of 2019 .*

*** Solution #21 is supporting two deployment scenarios through different operational improvements and technological changes , the first one is the Collaborative NOP which is part of the PCP deployment and the second one is the Collaborative Airport (AOP phase 2) which is a continuation of the first one but not yet included in the PCP deployment .*

EOC Digital AIM and MET services

PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
			In deployment phase: key SESAR Solutions				
	Digitally enhanced briefing	#34	Digital integrated briefing		B	Not applicable	Not applicable
			In development phase: Key Solutions approaching maturity				
	Improved aviation AIM and MET services through automation and digitalisation	PJ.18-04a	Aeronautical information management (AIM) information		B	Not applicable	Not applicable
		PJ.18-04b	Meteorological (MET) information		B	Not applicable	Not applicable
			In development phase: Key R&D activities				
	Aircraft as an AIM/MET sensor and consumer	PJ.14-W2-110	Aircraft as an AIM/MET sensor and consumer		C	PJ.18-04c	MET and AIM information services in the aircraft information domain
			Additional R&D activities in development				
	Advanced automated MET system	PJ.05-05	Advanced automated MET system		B	Not applicable	Not applicable
	Static aeronautical data service	PJ.15-10	Static aeronautical data service		B	Not applicable	Not applicable
	Aeronautical digital map service	PJ.15-11	Aeronautical digital map service		B	Not applicable	Not applicable

EOC U-space services

PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
			In deployment phase: key SESAR Solutions				
	U-space U1 — foundation services	U1S-01	e-Registration service		A	Not applicable	Not applicable
		U1S-02	e-Identification service		A	Not applicable	Not applicable
		U1S-03	Pre-tactical geo-fencing service		A	Not applicable	Not applicable
			In development phase: Key Solutions approaching maturity				
	U-space U2 — initial services	U2S-01	Tactical geo-fencing service		B	Not applicable	Not applicable
		U2S-02	Emergency management service		B	Not applicable	Not applicable
		U2S-03	Strategic de-confliction service		B	Not applicable	Not applicable
		U2S-04	Weather information service		B	Not applicable	Not applicable
		U2S-05	Tracking service		B	Not applicable	Not applicable
		U2S-06	Flight planning management service		B	Not applicable	Not applicable
		U2S-07	Monitoring service		B	Not applicable	Not applicable
		U2S-08	Traffic information service		B	Not applicable	Not applicable
		U2S-09	Drone aeronautical information management service		B	Not applicable	Not applicable
		U2S-10	Procedural interface with ATC service		B	Not applicable	Not applicable
			In development phase: Key R&D activities				
	U-space U3 — advanced services	U3S-01	Dynamic geo-fencing service		C	Not applicable	Not applicable
		U3S-02	Tactical de-confliction service		C	Not applicable	Not applicable
		U3S-03	Collaborative interface with ATC service		C	Not applicable	Not applicable
		U3S-04	Dynamic capacity management service		C	Not applicable	Not applicable

EOC Virtualisation of service provision

PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
			In development phase: Key Solutions approaching maturity				
	Remotely provided ATS for multiple aerodromes	PJ.05-02	Multiple remote tower module		B	Not applicable	Not applicable
	Virtual centre concept	PJ.16-03	Enabling rationalisation of infrastructure using virtual centre based technology		C	Not applicable	Not applicable
			In development phase: Key R&D activities				
	Multiple remote towers and remote tower centre	PJ.05-W2-35	Multiple remote towers and remote tower centre		C	PJ.05-03	Remote tower centre with flexible allocation of aerodromes to multiple remote tower modules
	HMI interaction modes for ATC centres and airport towers	PJ.05-W2-97	HMI interaction modes for airport tower		C	PJ.16-04	Workstation, controller productivity
		PJ.10-W2-96	HMI interaction modes for ATC centre		C	PJ.16-04	Workstation, controller productivity
	Delegation of services amongst ATSUs	PJ.10-W2-93	Delegation of services amongst ATSUs		C	PJ.15-09	Delegation of services and contingency
			Additional SESAR Solutions in deployment				
	Single remote tower operations for medium traffic volumes	#12	Single remote tower operations for medium traffic volumes		B	Not applicable	Not applicable
	Remotely provided air traffic service for contingency situations at aerodromes	#13	Remotely provided air traffic service for contingency situations at aerodromes		B	Not applicable	Not applicable
	Remote tower for two low density aerodromes	#52	Remote tower for two low density aerodromes		B	Not applicable	Not applicable
	ATC and AFIS service in a single low density aerodrome from a remote CWP	#71	ATC and AFIS service in a single low density aerodrome from a remote CWP		B	Not applicable	Not applicable

EOC Airport and TMA performance

PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
			In deployment phase: key SESAR Solutions				
✓	Airport safety nets	#02	Airport safety nets for controllers - conformance monitoring alerts and detection of conflicting ATC clearances		A	Not applicable	Not applicable
✓	Automated assistance to controller for surface movement planning and routing	#22	Automated assistance to controller for surface movement planning and routing		A	Not applicable	Not applicable
✓	Departure manager (DMAN) synchronised with pre-departure sequencing	#53	Pre-departure sequencing supported by route planning		A	Not applicable	Not applicable
		#106	Departure manager (DMAN) baseline for integrated AMAN-DMAN		A	Not applicable	Not applicable
✓	Enhanced TMA using RNP-based operations	#09	Enhanced terminal operations with automatic RNP transition to ILS/GLS		A	Not applicable	Not applicable
		#51	Enhanced terminal operations with LVP procedures		B	Not applicable	Not applicable
		#62	P-RNAV in a complex TMA		B	Not applicable	Not applicable
✓	Time-based separation for final approach	#64	Time-based separation		A	Not applicable	Not applicable
✓	Arrival manager (AMAN) extended to en-route airspace	#05	Extended arrival management (AMAN) horizon		A	Not applicable	Not applicable
	Enhanced airport safety nets	#01	Runway status lights		A	Not applicable	Not applicable
	Airport safety nets vehicle	#04	Enhanced traffic situational awareness and airport safety nets for the vehicle drivers		A	Not applicable	Not applicable
	Integrated surface management	#47	Guidance assistance through airfield ground lighting		A	Not applicable	Not applicable
	Enhanced AMAN/DMAN integration	#54	Flow-based integration of arrival and departure management		B	Not applicable	Not applicable
			In development phase: Key Solutions approaching maturity				
	Efficient aircraft separation during take-off and final approach	PJ.02-01	Wake turbulence separation optimization		B	Not applicable	Not applicable
		PJ.02-03	Minimum-pair separations based on RSP		B	Not applicable	Not applicable
	Enhanced arrival procedures	PJ.02-02	Enhanced arrival procedures		B	Not applicable	Not applicable
	Enhanced visual operations	PJ.03a-04	Enhanced visual operations		B	Not applicable	Not applicable
	Traffic optimisation on single- and multiple-runway airports	PJ.02-08	Traffic optimisation on single- and multiple-runway airports		B	Not applicable	Not applicable
	Traffic alerts for pilots for airport operations	PJ.03b-05	Traffic alerts for pilots for airport operations		B	Not applicable	Not applicable

EOC Airport and TMA performance (continued)

PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
			In development phase: Key R&D activities				
	Dynamic extended TMAs for advanced CCO/CDO and improved arrival and departure operations	PJ.01-W2-08	Dynamic E-TMA for advanced continuous climb and descent operations and improved arrival and departure operations		C	PJ.01-02 PJ.01-03B PJ.18-02a	Use of arrival and departure management information for traffic optimisation within the TMA Dynamic E-TMA for advanced continuous climb and descent operations Trajectory based operations (TBO)
	Digital evolution of integrated surface management	PJ.02-W2-21	Digital evolution of integrated surface management		C	PJ.03a-01 PJ.03b-01	Enhanced guidance assistance to aircraft and vehicles on the airport surface combined with routing Enhanced airport safety nets for controllers
	Next generation AMAN for a 4D environment	PJ.01-W2-02	Next generation AMAN for a 4D environment		C	PJ.01-01 PJ.18-02a	Extended arrival management with overlapping AMAN operations and interaction with DCB and CTA Trajectory based operations (TBO)
	Advanced geometric GNSS-based procedures in TMAs	PJ.02-W2-04	Advanced geometric GNSS-based procedures in TMAs		C	PJ.01-03A PJ.02-11	Improved parallel operations Enhanced terminal area for efficient curved operation
	Evolution of separation minima for increased runway throughput	PJ.02-W2-14	Evolution of separation minima for increased runway throughput		C	Not applicable	Not applicable
			Additional SESAR Solutions in deployment				
	Arrival management into multiple airports	#08	Arrival management into multiple airports		B	Not applicable	Not applicable
	Continuous descent operations (CDO)	#11	Continuous descent operations (CDO)		A	Not applicable	Not applicable
	D-TAXI service for CPDLC application	#23	D-TAXI service for CPDLC application		A	Not applicable	Not applicable
	Virtual block control in LVPs	#48	Virtual block control in LVPs		A	Not applicable	Not applicable
	Enhanced ground controller situation awareness in all weather conditions	#70	Enhanced ground controller situation awareness in all weather conditions		A	Not applicable	Not applicable
	Point merge in complex TMA	#107	Point merge in complex TMA		B	Not applicable	Not applicable
	AMAN and point merge	#108	AMAN and point merge		A	Not applicable	Not applicable
	De-icing management tool	#116	De-icing management tool		A	Not applicable	Not applicable
	Reducing landing minima in low visibility conditions using enhanced flight vision systems (EFVS)	#117	Reducing landing minima in low visibility conditions using enhanced flight vision systems (EFVS)		A	Not applicable	Not applicable
			Additional R&D activities in development				
	Approach improvement through assisted visual separation	PJ.01-07	Approach improvement through assisted visual separation		B	Not applicable	Not applicable
	E-AMAN service	PJ.15-02	E-AMAN service		C	Not applicable	Not applicable
	Safety support tools for avoiding runway excursions	PJ.02-W2-25	Safety support tools for avoiding runway excursions		C	PJ.03b-06	Safety support tools for avoiding runway excursions
	Enhanced navigation and accuracy in low-visibility conditions on airport surfaces	PJ.03a-03	Enhanced navigation and accuracy in low-visibility conditions on airport surfaces		B	Not applicable	Not applicable
	Enhanced airport safety alerts for controller and pilot	PJ.03b-03	Conformance monitoring safety net for pilots		B	Not applicable	Not applicable
	Improved access to secondary airports	PJ.02-W2-17	Improved access to secondary airports		C	PJ.02-06	Improved access into secondary airports in low visibility conditions

EOC Fully dynamic and optimised airspace

PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
			In deployment phase: key SESAR Solutions				
		#33	Free Route through free routing for flights both in cruise and vertically evolving above a specified flight Level		A	Not applicable	Not applicable
		#32	Free Route through the use of direct routing		A	Not applicable	Not applicable
	Free Route	#65	User-preferred routing		A	Not applicable	Not applicable
		PJ.06 - 01	*Optimized traffic management to enable Free Routing in high and very high complexity environments **		A	Not applicable	Not applicable
		#66	Automated support for dynamic sectorisation		A	Not applicable	Not applicable
	Airspace management and advanced flexible use of airspace	#31	Variable profile military reserved areas and enhanced (further automated) civil-military collaboration		B	Not applicable	Not applicable
			In development phase: Key Solutions approaching maturity				
	High-productivity controller team organisation	PJ.10-01a	High-productivity controller team organisation		B	Not applicable	Not applicable
			In development phase: Key R&D activities				
	Flight-centric ATC and improved distribution of separation responsibility in ATC	PJ.10-W2-73	Flight-centric ATC and improved distribution of separation responsibility in ATC		C	PJ.10-01b PJ.10-06 PJ.10-01c	Flight-centric ATC Generic' (non-geographical) controller validations Collaborative control
	Dynamic airspace configuration	PJ.09-W2-44	Dynamic airspace configurations (DAC)		C	PJ.08-01	Management of dynamic airspace configurations
	Mission trajectories management with integrated dynamic mobile areas type 1 and type 2	PJ.07-W2-40	Mission trajectories management with integrated dynamic mobile areas type 1 and type 2		C	PJ.07-03 PJ.08-01	Mission trajectory driven processes Management of dynamic airspace configurations
			Additional SESAR Solutions in deployment				
	Optimised route network using advanced RNP	#10	Optimised route network using advanced RNP		B	Not applicable	Not applicable
	Multi-sector planning	#63	Multi-sector planning		A	Not applicable	Not applicable
	Sector team operations - en-route air traffic organiser	#104	Sector team operations - en-route air traffic organiser		A	Not applicable	Not applicable
	Basic EAP (extended ATC planning function)	#118	Basic EAP (extended ATC planning function)		A	Not applicable	Not applicable
			Additional R&D activities in development				
	Collaborative control and multi-sector planner in en-route	PJ.10-W2-70	Collaborative control and multi-sector planner in en-route		C	PJ.10-01c	Collaborative control
	Management of performance based free routing in lower airspace	PJ.06-02	Management of performance based free routing in lower airspace		B	Not applicable	Not applicable
	Dynamic airspace configuration supporting moving areas	PJ.08-02	Dynamic airspace configuration supporting moving areas		C	Not applicable	Not applicable

**Solutions that are still in the pipeline for deployment but are part of PCP expected to be mature by the end of 2019 .*

EOC Trajectory-based operations

PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
			In deployment phase: key SESAR Solutions				
		#115	Extended projected profile (EPP) availability on ground		B	Not applicable	Not applicable
	Initial trajectory information sharing (i4D)	*PJ.18-06a*	*ATC planned trajectory performance improvement **		C	Not applicable	Not applicable
		PJ.18-06b	*Tactical and NM trajectory performance improvement **		B	Not applicable	Not applicable
	Enhanced safety nets	#60	Enhanced short-term conflict alert (STCA) for terminal manoeuvring areas (TMAs)		A	Not applicable	Not applicable
		#69	Enhanced STCA with down-linked parameters		B	Not applicable	Not applicable
			In development phase: Key Solutions approaching maturity				
	eFPL supporting SBT transition to RBT	PJ.18-02c	eFPL supporting SBT transition to RBT		C	Not applicable	Not applicable
			In development phase: Key R&D activities				
	Improved ground trajectory predictions enabling future automation tools	PJ.18-W2-53	Improved ground trajectory predictions enabling future automation tools		C	PJ.10-02a1 PJ.10-02a2 PJ.10-02b	Improved performance in the provision of separation without use of ADS-C/EPP data Improved performance in the provision of separation with use of ADS-C/EPP data Advanced separation management
	RBT revision supported by datalink and increased automation	PJ.18-W2-57	RBT revision supported by datalink and increased automation		C	PJ.18-02a	Trajectory based operations (TBO)
	Enhanced integration of AU trajectory definition and network management processes	PJ.07-W2-38	Enhanced integration of AU trajectory definition and network management processes		C	PJ.07-01	AU processes for trajectory definition
	Improved vertical profiles through enhanced vertical clearances	PJ.18-W2-56	Improved vertical profiles through enhanced vertical clearances		C	PJ.01-03B PJ.18-02a	Dynamic E-TMA for advanced continuous climb and descent operations Improved performance in the provision of separation Trajectory based operations (TBO)
			Additional SESAR Solutions in deployment				
	Controlled time of arrival (CTA) in medium density / medium complexity environment	#06	Controlled time of arrival (CTA) in medium density / medium complexity environment		B	Not applicable	Not applicable
	MTCD and conformance monitoring tool	#27	MTCD and conformance monitoring tool		A	Not applicable	Not applicable
	ACAS ground monitoring and presentation system	#100	ACAS ground monitoring and presentation system		B	#58	Display and use of ACAS resolution advisory downlink on the controller working position
	Extended hybrid surveillance	#101	Extended hybrid surveillance		A	Not applicable	Not applicable
	Enhanced airborne collision avoidance system (ACAS)	#105	Enhanced airborne collision avoidance system (ACAS)		A	Not applicable	Not applicable
			Additional R&D activities in development				
	Airborne spacing flight deck interval management	PJ.01-05	Airborne spacing flight deck interval management		B	Not applicable	Not applicable
	Enhanced short-term conflict alert (STCA) and non transgression zone (NTZ) ground based safety nets making use of DAPs information	PJ.11-G1	Enhanced short-term conflict alert (STCA) and non transgression zone (NTZ) ground based safety nets making use of DAPs information		C	Not applicable	Not applicable
	Trajectory prediction service	PJ.18-W2-88	Trajectory prediction service		C	PJ.15-08	Trajectory prediction service

**Solutions that are still in the pipeline for deployment but are part of PCP expected to be mature by the end of 2019 .*

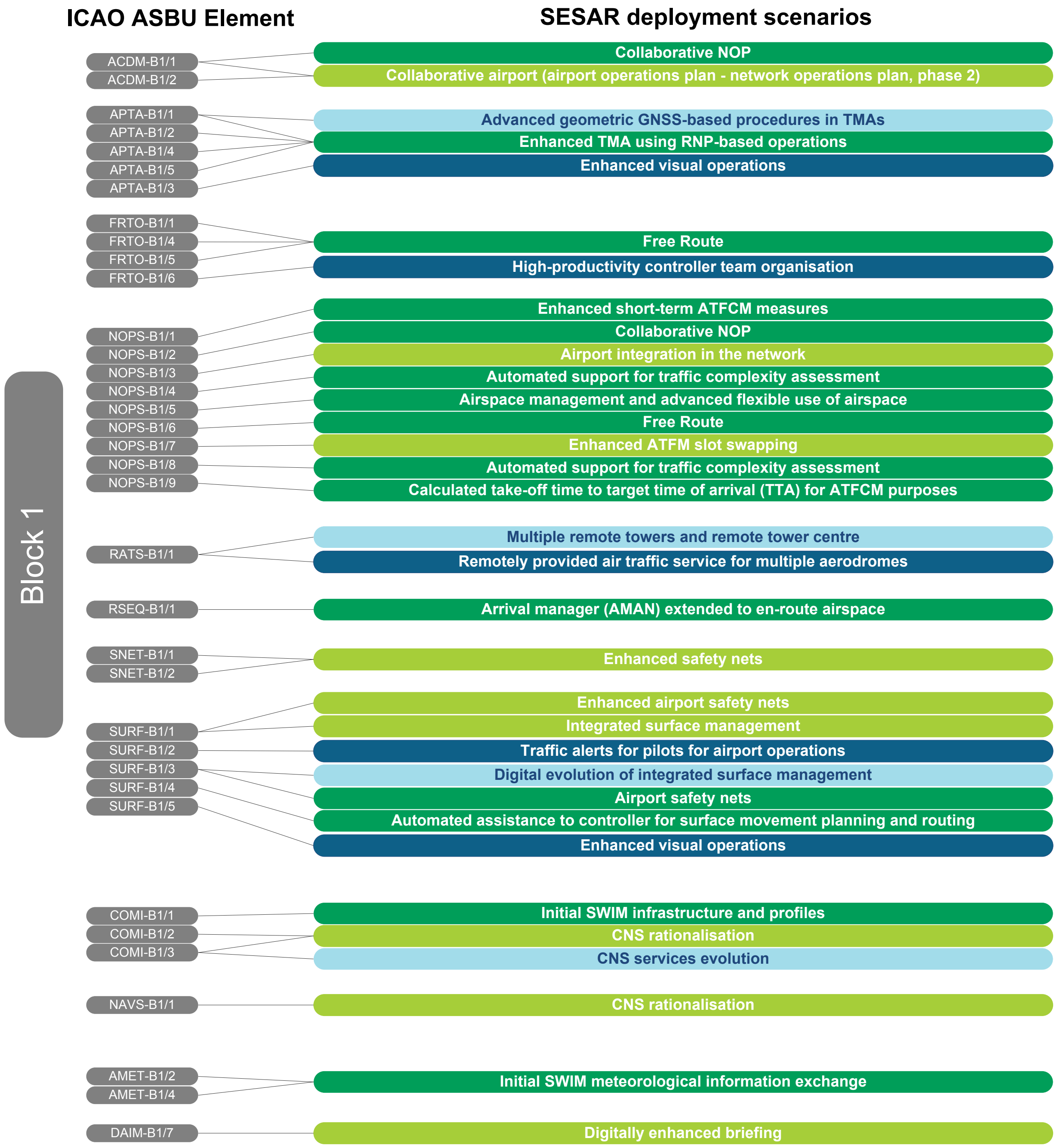
EOC Multimodal mobility and integration of all airspace users

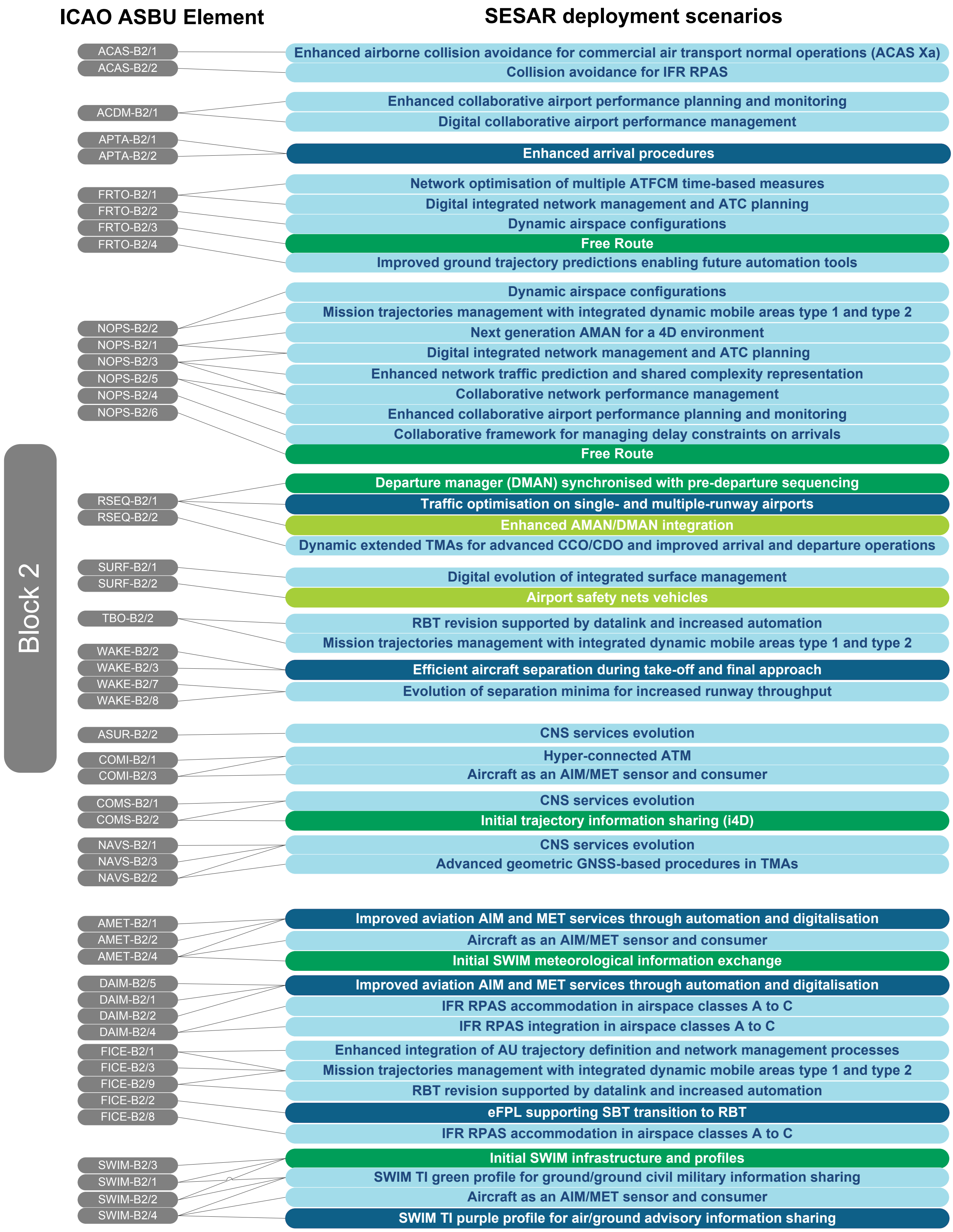
PCP	Chapters 4 and 5 Deployment Scenario	Solution code	Names of Solutions and activities	Key Feature	MP Vision phase	Following from Solution	Solution name
			In deployment phase: key SESAR Solutions				
	Optimised low-level IFR routes for rotorcraft	#113	Optimised low-level IFR routes for rotorcraft		B	Not applicable	Not applicable
			In development phase: Key Solutions approaching maturity				
	Independent rotorcraft operations at airports	PJ.02-05	Independent rotorcraft operations at the airports		C	Not applicable	Not applicable
	Enhanced rotorcraft and GA operations in the TMA	PJ.01-06	Enhanced rotorcraft and GA operations in the TMA		B	Not applicable	Not applicable
			In development phase: Key R&D activities				
	Collision avoidance for IFR RPAS	PJ.13-W2-111	Collision avoidance for IFR RPAS		B	PJ.11-A2	Collision avoidance for IFR RPAS
	IFR RPAS accommodation in airspace classes A to C	PJ.13-W2-115	IFR RPAS accommodation in airspace classes A to C		C	PJ.10-05	IFR RPAS integration
	IFR RPAS integration in airspace classes A to C	PJ.13-W2-117	IFR RPAS integration in airspace classes A to C		C		
			Additional R&D activities in development				
	Advanced rotorcraft operations in the TMA	PJ.01-W2-06	Advanced rotorcraft operations in the TMA		C	Not applicable	Not applicable
	Development of new services similar to FIS-B to support ADS-B solutions for General Aviation	PJ.14-02-05	Development of new services similar to FIS-B to support ADS-B solutions for General Aviation		B	Not applicable	Not applicable
	ACAS evolution for rotorcraft and general aviation	PJ.11-A4	Airborne collision avoidance for general aviation and rotorcraft (ACAS Xp)		B	Not applicable	Not applicable
	Surface operations by RPAS	PJ.03a-09	Surface operations by remotely-piloted aircraft systems (RPAS)		B	Not applicable	Not applicable

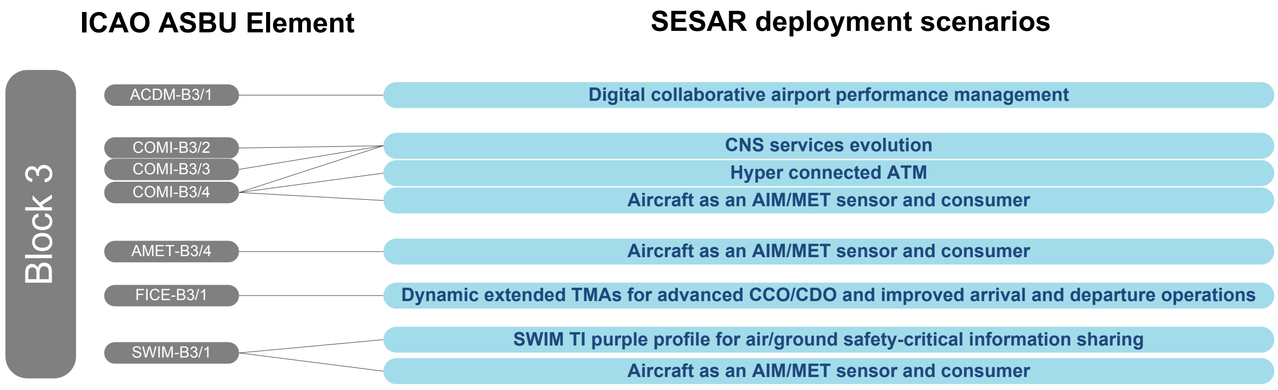
ANNEX B.

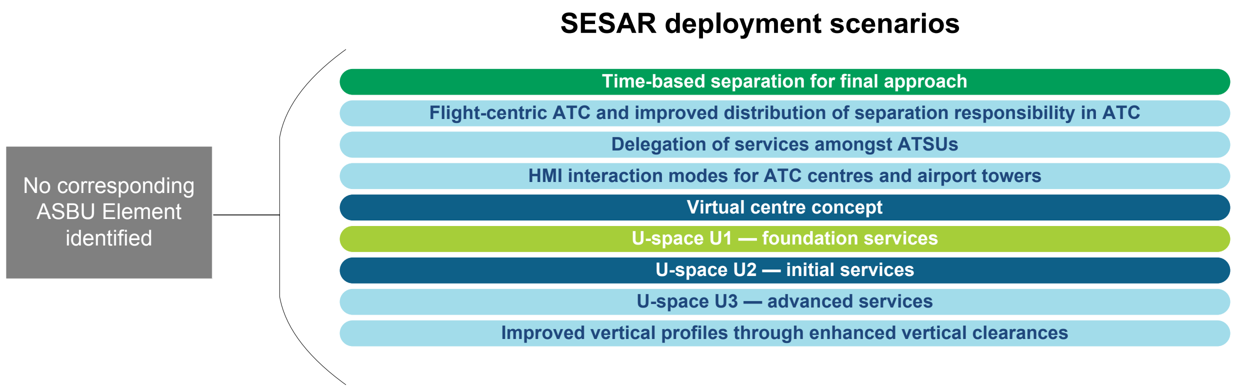
MAPPING SESAR CHANGES TO 2019 ICAO FRAMEWORK

This annex shows the mapping between the SESAR deployment scenarios and the ICAO Aviation System Block Upgrades (ASBU) Elements. The ICAO framework of 2019 shows a finer granularity than its predecessor.




ICAO ASBU Element
SESAR deployment scenarios
Block 2
ACAS-B2/1
ACAS-B2/2
ACDM-B2/1
APTA-B2/1
APTA-B2/2
FRTO-B2/1
FRTO-B2/2
FRTO-B2/3
FRTO-B2/4
NOPS-B2/2
NOPS-B2/1
NOPS-B2/3
NOPS-B2/5
NOPS-B2/4
NOPS-B2/6
RSEQ-B2/1
RSEQ-B2/2
SURF-B2/1
SURF-B2/2
TBO-B2/2
WAKE-B2/2
WAKE-B2/3
WAKE-B2/7
WAKE-B2/8
ASUR-B2/2
COMI-B2/1
COMI-B2/3
COMS-B2/1
COMS-B2/2
NAVS-B2/1
NAVS-B2/3
NAVS-B2/2
AMET-B2/1
AMET-B2/2
AMET-B2/4
DAIM-B2/5
DAIM-B2/1
DAIM-B2/2
DAIM-B2/4
FICE-B2/1
FICE-B2/3
FICE-B2/9
FICE-B2/2
FICE-B2/8
SWIM-B2/3
SWIM-B2/1
SWIM-B2/2
SWIM-B2/4
Enhanced airborne collision avoidance for commercial air transport normal operations (ACAS Xa)
Collision avoidance for IFR RPAS
Enhanced collaborative airport performance planning and monitoring
Digital collaborative airport performance management
Enhanced arrival procedures
Network optimisation of multiple ATFCM time-based measures
Digital integrated network management and ATC planning
Dynamic airspace configurations
Free Route
Improved ground trajectory predictions enabling future automation tools
Dynamic airspace configurations
Mission trajectories management with integrated dynamic mobile areas type 1 and type 2
Next generation AMAN for a 4D environment
Digital integrated network management and ATC planning
Enhanced network traffic prediction and shared complexity representation
Collaborative network performance management
Enhanced collaborative airport performance planning and monitoring
Collaborative framework for managing delay constraints on arrivals
Free Route
Departure manager (DMAN) synchronised with pre-departure sequencing
Traffic optimisation on single- and multiple-runway airports
Enhanced AMAN/DMAN integration
Dynamic extended TMAs for advanced CCO/CDO and improved arrival and departure operations
Digital evolution of integrated surface management
Airport safety nets vehicles
RBT revision supported by datalink and increased automation
Mission trajectories management with integrated dynamic mobile areas type 1 and type 2
Efficient aircraft separation during take-off and final approach
Evolution of separation minima for increased runway throughput
CNS services evolution
Hyper-connected ATM
Aircraft as an AIM/MET sensor and consumer
CNS services evolution
Initial trajectory information sharing (i4D)
CNS services evolution
Advanced geometric GNSS-based procedures in TMAs
Improved aviation AIM and MET services through automation and digitalisation
Aircraft as an AIM/MET sensor and consumer
Initial SWIM meteorological information exchange
Improved aviation AIM and MET services through automation and digitalisation
IFR RPAS accommodation in airspace classes A to C
IFR RPAS integration in airspace classes A to C
Enhanced integration of AU trajectory definition and network management processes
Mission trajectories management with integrated dynamic mobile areas type 1 and type 2
RBT revision supported by datalink and increased automation
eFPL supporting SBT transition to RBT
IFR RPAS accommodation in airspace classes A to C
Initial SWIM infrastructure and profiles
SWIM TI green profile for ground/ground civil military information sharing
Aircraft as an AIM/MET sensor and consumer
SWIM TI purple profile for air/ground advisory information sharing





LEGEND

Prioritised deployment scenarios

- In deployment phase: Key SESAR Solutions (PCP)
- In deployment phase: Key SESAR Solutions
- In development phase: Key Solutions approaching maturity
- In development phase: Key R&D activities

ANNEX C.

EVOLUTION OF THE UNDERLYING CNS TECHNOLOGIES

The purpose of the CNS critical path is to identify and reflect emerging CNS technologies by time and their links with the most relevant deployment scenarios in support of the EOCs.

The figure below shows the underlying CNS technologies and services, and the changes needed through the 'mature', 'approaching maturity' and 'key R&D' deployment scenarios with respect to new technologies (e.g. ACAS X) and new concepts (e.g. TBO evolution, the virtual-centre concept, U-space management, SWIM evolution). It should be noted that the links made in the figure do not include all the possible connections and only highlight the critical connections to deployment scenarios

The ground and space infrastructures are identified with circles, while the airborne technology is marked with a square. The presence of a circle and a square indicates the need for synchronisation. It is assumed that backward compatibility will be maintained for some services (e.g. SBAS systems providing DFMC services will continue to provide an SBAS L1 service to maintain backwards compatibility and support SBAS L1-equipped users.)

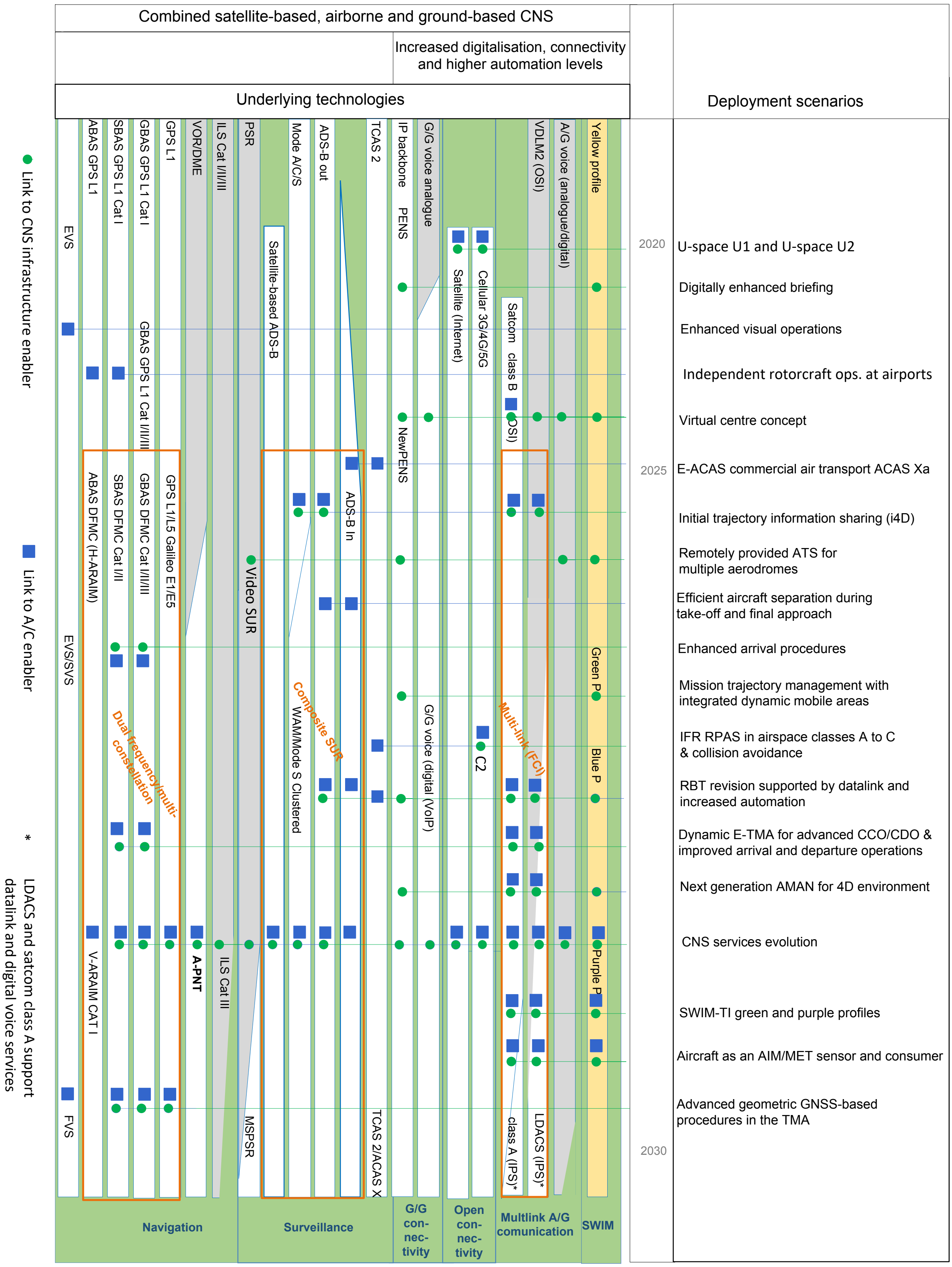
Only new technologies or adaptations of existing technologies required to support the full deployment are identified (i.e. video surveillance for remote ATS for multiple aerodromes but no new requirement for surveillance, new ADS-B OUT standards). Technologies that are part of the Master Plan but which are not critical for the deployment scenario are not included in the figure. For example, AeroMACS (Aeronautical Mobile Airport Communications System) is available for implementation based on local business cases. It provides a wideband data and voice solution to support ground-ground services and services to mobile users (e.g. aircraft, vehicles) at airports, thus relieving VDL 2 in the busiest airports.

To express the stepped approach between the current situation and the projected infrastructure, three key milestones, starting from 2025, are highlighted.

- The multilink concept will enable the seamless management of multiple digital datalink technologies. It will combine technologies considered by ICAO (L-DACS, SATCOM, AeroMACS) to support safety-critical applications and will integrate open connectivity opportunities (e.g. 5G).
- The next generation of GNSS DFMC aircraft-based augmentation system (ABAS)/SBAS/GBAS receivers, which allows the use of multiple frequencies from various satellite constellations, will increase capacity in low-visibility conditions and improve the robustness of the overall system.
- Composite surveillance starts with extensive deployment of the ADS-B OUT capability, allowing the optimisation of surveillance infrastructure, supported by a mix of ADS-B, WAM and mode S secondary radars.

Both the integrated backbone and the MON (plus a few additional technologies such as ACAS and EVS/SVS) contribute to the eight key evolution directions.

An additional element shown in the figure (data traffic evolution) requires adding datalink capacity to sustain the growth in aviation traffic and the trend towards higher data volumes exchanged between aircraft and other systems (owing to more demand, for example for ATM services and information services, and owing to an increase in aircraft operational data exchanges, for example of large engine maintenance files). The requirement for additional capacity is in addition to requirements for higher performance (e.g. lower latency, high availability).


Combined satellite-based, airborne and ground-based CNS
Increased digitalisation, connectivity and higher automation levels
Underlying technologies
Deployment scenarios
2020
2025
2030
U-space U1 and U-space U2
Digitally enhanced briefing
Enhanced visual operations
Independent rotorcraft ops. at airports
Virtual centre concept
E-ACAS commercial air transport ACAS Xa
Initial trajectory information sharing (i4D)
Remotely provided ATS for multiple aerodromes
Efficient aircraft separation during take-off and final approach
Enhanced arrival procedures
Mission trajectory management with integrated dynamic mobile areas
IFR RPAS in airspace classes A to C & collision avoidance
RBT revision supported by datalink and increased automation
Dynamic E-TMA for advanced CCO/CDO & improved arrival and departure operations
Next generation AMAN for 4D environment
CNS services evolution
SWIM-TI green and purple profiles
Aircraft as an AIM/MET sensor and consumer
Advanced geometric GNSS-based procedures in the TMA
Link to CNS infrastructure enabler
Link to A/C enabler
* LDACS and satcom class A support datalink and digital voice services
EVS
EVS/SVS
FVS
ABAS GPS L1
ABAS DFMC (H-ARAIM)
V-ARAIM CAT I
SBAS GPS L1 Cat I
SBAS DFMC Cat I/II
GBAS GPS L1 Cat I
GBAS GPS L1 Cat I/II/III
GBAS DFMC Cat I/II/III
GPS L1
GPS L1/L5 Galileo E1/E5
Dual frequency/multi-constellation
VOR/DME
A-PNT
ILS Cat I/II/III
ILS Cat III
PSR
Video SUR
MSPSR
Satellite-based ADS-B
Mode A/C/S
WAM/Mode S Clustered
Composite SUR
ADS-B out
ADS-B In
TCAS 2
TCAS 2/ACAS X
IP backbone PENS
NewPENS
G/G voice analogue
G/G voice (digital (VoIP)
Satellite (Internet)
Cellular 3G/4G/5G
C2
Satcom class B (OSI)
class A (IPS)*
VDLM2 (OSI)
LDACS (IPS)*
Multi-link (FCI)
A/G voice (analogue/digital)
Yellow profile
Green P
Blue P
Purple P
Navigation
Surveillance
G/G con-nec-tivity
Open con-nec-tivity
Multlink A/G comunication
SWIM

ANNEX D.

AN ATM DIGITAL INDEX

The table below shows an initial proposal for a digital index built along the lines of the EU digital single market initiative's DESI. The fitness for purpose of this proposed index still has to be tested using actual data before it can be used as a means of measuring the uptake of digitalisation among ATM stakeholders.

Dimension	Sub-dimension	Indicator	Description	KPI measured per	Unit	Weight
1. Connectivity & information sharing	1a Ground to ground connectivity	1a1 Implementation of IP based connectivity	Existence or not of connection to an ATM IP backbone	All stakeholders, including airspace users	Score (0 -1) -> 0-100%	1
		1a2 Usage of IP based connectivity	Share of external interfaces for ATM related operations implemented on SWIM/IP infrastructure	All stakeholders, including airspace users	0-100 %	1
	1b Air to ground connectivity	1b1 Datalink implementation and coverage	Three level indicator: 0=Use of voice communication only 1= Use of datalink but not IP based 2= Use of IP based datalink	ANSPs AUs	Score (0 -2) -> 0=0% 1=50% 2=100%	1
		1b2 Datalink usage against full datalink services	Share of information that is shared using datalink	ANSPs	0-100%%	1
2. Automation	2a Degree of automation	2a1 Level of ATCO work automation	Working position (ATCo + automation) productivity improvement driven by system automation	ANSPs	1 = 0% 10=100%	2
3. Virtualisation	3a Remote provision of ANS	3a1 Implementation of virtual and remote centers	Share of capabilities that are implemented independently from the geographical location where they are delivered (i.e., virtual centres & remote towers)	ANSPs	0-100%	2
4. Industry liberalisation	4a Open industry policy	4a1 Availability of API interfaces	Existence or not of well-defined and affordable API interfaces provided to external stakeholders (e.g., SMEs)	ANSPs, NM	Score (0 -1) 0 = 0% 1 = 100%	1

ANNEX E.

ABBREVIATIONS

AAS	Airspace architecture study
ABAS	Aircraft-based augmentation system
ACAS	Airborne collision avoidance system
A-CDM	Airport – collaborative decision making
ADF	Automatic direction finder
ADS-B	Automatic dependent surveillance-broadcast
ADS-C	Automatic dependent surveillance-contract
ADSP	ATM data service provider
AeroMACS	Aeronautical mobile airport communications system
AF	ATM functionality
AFIS	Aerodrome flight information service
AFISO	Aerodrome flight information service officer
A-FUA	Advanced flexible use of airspace
A/A	Air/air
A/G	Air/ground
AGL	Airfield ground lighting
AI	Artificial intelligence
AIM	Aeronautical information management
AIRM	Aeronautical information reference model
AIS	Aeronautical information services
AIXM	Aeronautical information exchange model
AMAN	Arrival manager
ANC13	13th ICAO Air Navigation Conference
ANS	Air navigation service
ANSP	Air navigation service provider
AO	Airport operations
AOC	Airline operation centre
AOP	Airport operations plan
APOC	Airport operations centre
A-PNT	Alternative position, navigation and timing
APP	Approach
ARES	Airspace reservation
ASAS	Airborne separation assistance/ assurance system
ASBU	Aviation system block upgrade
ASM	Airspace management
ASMA	Arrival sequencing and metering area
A-SMGCS	Advanced surface movement guidance and control system
ASPA	ASAS spacing
ATC	Air traffic control
ATCO	Air traffic control officer
ATFCM	Air traffic flow and capacity management
ATFM	Air traffic flow management
ATM	Air traffic management
ATM RPP	ATM requirements and performance panel
ATN	Aeronautical telecommunications network
ATS	Air traffic service(s)
ATSEP	Air traffic safety electronics personnel
ATSU	Air traffic service unit
AU	Airspace user
AUP	Airspace use plan
AUTOMETAR	Automated METAR (automated weather observation)
B2B	Business-to-business
BA	Business aviation
BVLOS	Beyond visual line of sight (for drone operations)
CAPP	Cockpit assisted pilot procedure
CAS	Calibrated Air Speed
CAT I/II/III	Category I/II/III (ICAO categories of precision approach and landing)
CAVS	CDTI assisted visual separation
CBA	Cost benefit analysis
CCO	Continuous climb operations
CDM	Collaborative decision-making
CDO	Continuous descent operations
CD&R	Conflict detection and resolution
CDTI	Cockpit display of traffic information
CEF	Connecting Europe facility
CHMI	Collaboration human machine interface (formally CFMU HMI)
CNL	Cancel message
CNS	Communication, navigation and surveillance
COM	Communication
CONOPS	Concept of operations

COTS	Commercial off-the-shelf
CP	Common projects
CPDLC	Controller-pilot datalink communications
CTA	Controlled time of arrival
CTOT	Calculated take-off time
CTR	Control zone
CVS	Combined vision system (to extend visual segment)
CWP	Controller work position

DAA	Dynamic airspace allocation
DAA	Detect and avoid (for IFR RPAS)
DAC	Dynamic airspace configuration
DAP	Downlinked aircraft parameters
DCB	Demand capacity balancing
DCT	Direct (direct routing)
DESI	Digital economy and society index
DFMC	Dual frequency multi-constellation
DMA	Dynamic mobile areas
DMAN	Departure manager
DME	Distance measuring equipment
DMR/IRS	Distance measuring equipment/inertial reference system
D-NOTAM	Digital NOTAM
DPI	Departure planning information
D-TAXI	Datalink taxi clearance service

EAP	Extended ATC planning function
EASA	European Aviation Safety Agency
E-AMAN	Extended AMAN
EASCG	European ATM standards coordination group
EC	European Commission
ECAC	European Civil Aviation Conference
EDA	European Defence Agency
EFB	Electronic flight bag
eFPL	Extended flight plan
EFS	Electronic flight strip
EFVS	Enhanced flight vision systems
EGNOS	European geostationary navigation overlay service
EHS	Enhanced surveillance
EOC	Essential operational change
E-OCVM	European operational concept validation methodology
EPAS	European plan for aviation safety
EPP	Extended projected profile
ESO	European Standardisation Organisation
E-TMA	Extended TMA
EU	European Union
EUR	Euro
EUROCAE	European organisation for civil aviation equipment
EVS	Enhanced vision systems

FAA	Federal aviation authority
FAB	Functional airspace block
FCI	Future communications infrastructure
FCU/MCP	Flight control unit/multifunction control panel
FF-ICE	Flight and flow information for a collaborative environment
FL	Flight level
FIR	Flight information region
FIS	Flight information service
FIS-B	Flight information service - broadcast
FIXM	Flight information exchange model
FO	Flight object
FOC	Full operational capability
FMS	Flight management systems
FOC	Flight operations centre
FRA	Free route airspace
FUA	Flexible use of airspace

G2G	Gate–to-gate
GA	General aviation
GANP	Global Air Navigation Plan
GAST-F	GBAS approach service type F - for operations to CAT II/III performance based on multi-constellation and dual frequencies
GAT	General air traffic
GBAS	Ground-based augmentation system
GDP	Gross domestic product
G/G	Ground/ground
GLS	GBAS landing system
GNSS	Global navigation satellite system
GPS	Global positioning system

HMI	Human-machine interface

i4D	Initial 4 dimensional trajectory (latitude, longitude, altitude and time)
IaaS	Infrastructure as a service
ICAO	International Civil Aviation Organisation
IFR	Instrument flight rules
ILS	Instrument landing system
IMP	Information management panel
INEA	Innovation and Networks Executive Agency
IOC	Initial operational capability

IOP	Flight object
IoT	Internet of things
IP	Internet protocol
ISMS	Information security management systems
ISRM	Information service reference model
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 omnidirectional radio 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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