SESAR JOINT UNDERTAKING

European ATM Master Plan

Making Europe the most efficient and environmentally friendly sky to fly in the world

2025 EDITION

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1. Executive summary

Air traffic management (ATM) is an essential safety- and security-critical infrastructure for Europe, ensuring all types of aircraft fly safely and as efficiently as possible.

Air traffic management at a crossroads

European ATM is at a crossroads. European airspace is experiencing increasing levels of congestion due to a mix of factors, including the year-on-year increase in the number of flights, while maintaining an excellent safety record. The ATM system has been struggling to keep up with the rising demand, which in 2019 led to an all-time high of nearly 11 million flights. In 2024, traffic volumes in many parts of the European Network exceeded 2019 levels, and forecasts show a yearly increase of around 5 % until 2030 and a rise to approximately 16 million flights by 2050. At the same time, the airspace will become more complex to manage, as new types of air vehicles – such as zero-emission aircraft, drones, and military and high-altitude aircraft – share the sky.

ATM is impacted by and has an impact on climate change. This is prompting the aviation industry to step up its efforts to improve the environmental sustainability of aviation, with the goal of becoming carbon neutral by 2050. In addition, geopolitical crises, security threats and natural events are all contributing to significant stress on aviation; the Russian war against Ukraine has reduced the airspace available for civil aviation in Europe by around 20 %.

Balancing these complex aspects while maintaining Europe's competitive edge in the global aviation system is a formidable challenge that no single ATM organisation or stakeholder can do alone. It requires a joint approach involving all stakeholders coming together to chart the way forward.

Today, innovation and the deployment of new ATM systems are not up to speed with the growing traffic levels, and there is an urgent need to prioritise actions that can address the operational needs and the performance of the network.

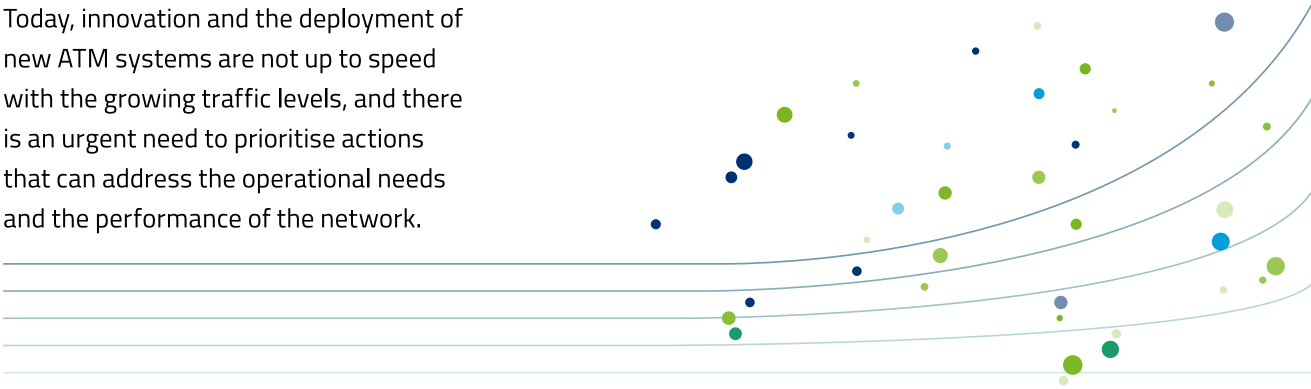
A roadmap for air traffic management modernisation

As part of the Single European Sky (SES), the European ATM Master Plan (hereafter referred to as 'the Master Plan') is the planning tool for ATM modernisation across Europe. It sets out the **vision** and **priorities** for the **Digital European Sky**, and for **making Europe the most efficient and environmentally friendly sky to fly in the world by 2045**.

> By 2045, all flights will be optimised from gate to gate through ensuring continuous connectivity between air–ground and ground–ground operations. European ATM will avoid any unnecessary fuel burn while also improving performance on non-CO_2 emissions, noise and local air quality. The system will be fully scalable and resilient, ready to adapt to fluctuating traffic demand and accommodating the growing diversity of aircraft, while achieving the highest safety and security levels. ATM will be fully integrated into a multimodal transport system.

The **twin digital and green transitions** are the central focus of the plan, which is structured around five technological levers for transformational change.

- **Trajectory-based operations.** Through these operations, data-enriched flight plans will allow aircraft to navigate very precisely along fuel-efficient routes, facilitated by ATM.



- **Greater data volumes through better air–ground and ground–ground communication.** The use of machine learning, artificial intelligence and big data analytics will enable ATM to operate smarter and safer.
- **Higher levels of automation between the flight deck and the ground.** Voice communication will no longer be the primary means of communication, as machine-to-machine applications will manage most routine tasks.
- **Human–machine teaming.** Through this process, air traffic controllers, air traffic safety electronics personnel, flight crew and operators will team up with the machines to deliver the highest quality of service.
- **Dynamic airspace.** This will enable the near-real-time configuration of airspace, and the system will be fully automated for certain phases of flight.

Added to these levers is a move to a data-driven and cloud-based **service-oriented architecture (SOA) delivery model**. This new approach, involving a shift of focus from assets to services, will enable the quicker deployment of new features, while improving the interoperability of operations, airspace and technology across air navigation service providers and other stakeholders.

Prioritisation and roll-out

The Single European Sky ATM Research (SESAR) project has delivered over **130 solutions**, many of which are already deployed across Europe and elsewhere. These deployments, notably the Common Project One, have already brought tangible benefits. Therefore, this edition of the Master Plan places emphasis on deployment, providing important direction for future investments, as well as standardisation and regulatory decision-making. With, for the first time ever, the prioritisation of **10 strategic deployment objectives** (SDOs), which need to be implemented by 2035, the aim is now to accelerate the uptake of mature solutions that will bring even more benefits. The 10 objectives address safety-critical features such as runway/taxiway incursions (SDO 1), environmental benefits for airports (SDO 2) and for all flights thanks to trajectory-based operations (SDO 5), improvements of capacity and scalability (SDOs 3, 4, 6 and 8), as well as the uptake of innovative air mobility (SDO 10). The transversal objectives related to air–ground connectivity (SDO 7) and to communication, navigation and surveillance (SDO 9) complete the selection.

The Single European Sky (SES) initiative of the EU includes the **SESAR project (Single European Sky ATM Research)**. SESAR defines, develops and deploys the innovative solutions that underpin the Master Plan, in support of the goals of SES, as well as broader EU policies, such as the sustainable and smart mobility strategy. This modernisation work is done in close coordination with the European Union Aviation Safety Agency, to ensure alignment between the Master Plan and the regulatory framework and accelerate deployment.

Furthermore, and again for the first time, this edition of the Master Plan defines phase D, the last phase of the Digital European Sky, by detailing **12 development priorities** to address the following challenges:

- the vision of making Europe the most efficient and environmentally friendly sky to fly in the world;
- the further integration of innovative air mobility;
- the emergence of higher airspace operations;
- the integration of the next generation of aircraft for zero-/low-emission aviation by 2035;
- the new security context for ATM in Europe.

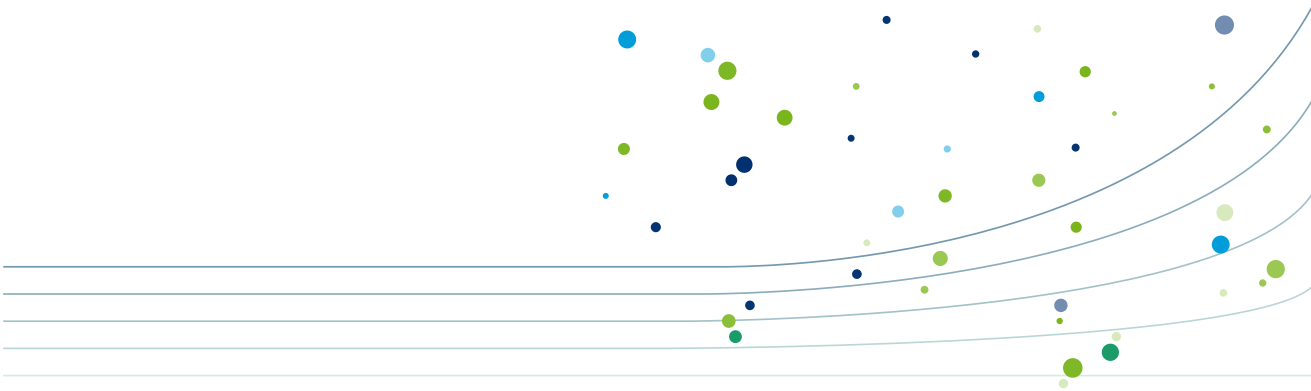
Expected benefits

The transformation outlined in the Master Plan holds significant value for the European economy and society at large. A more efficient and reliable aviation system will enhance connectivity, supporting competitiveness and economic development across the continent. Improving the predictability of traffic and ensuring on-time arrivals will significantly improve the passenger experience. It is estimated that every euro invested in deploying SESAR solutions will result, by 2050, in a return on investment for SESAR investors of **EUR 17, increasing to EUR 53 taking into account the broader socio-economic benefits for Europe**. In 2040, SESAR investors will already see a return on investment of EUR 7 for every euro invested.

In terms of sustainability, it is estimated that up to **400 million tonnes of CO2 could be saved by 2050**, with 100 million tonnes of CO_2 already saved by 2035 and 200 million tonnes by 2040. This is equivalent to close to 3 years' worth of total CO_2 emissions from aviation in Europe. Other environmental benefits of the transformation will include improved air quality, reduced noise pollution and a more resilient and sustainable air transport system.

Conditions for success

There are several major conditions that must be met to implement the Digital European Sky. These include a fit-for-purpose economic and technical regulatory framework; support for early movers; a synchronised and harmonised deployment, where needed; the concentration of all research resources on the development priorities; and the involvement of the entire ATM workforce in managing the transformation.



2. Introduction

Air traffic management (ATM) is a central component of the air transport ecosystem and provides essential safety- and security-critical services for Europe. The main objective of ATM is to ensure that all types of aircraft fly safely and as efficiently as possible. ATM relies on a complex organisation of procedures and technologies, requiring a high level of coordination, harmonisation and interoperability between all stakeholders. It plays a crucial role in supporting economic activities and connecting people across the globe. This chapter provides context for the European ATM Master Plan, explaining the drivers of this new edition and how it is structured.

Aviation is in the spotlight because of environmental issues linked to the consumption of fossil fuels and the resulting emissions (CO_2/non-CO_2), local air quality and noise. On a global scale, aviation contributes approximately 2–3 % of total anthropogenic CO_2 emissions. However, as other industries transition to cleaner energy sources at a faster rate, the relative proportion of aviation emissions is anticipated to increase over the coming years. CO_2 emissions for intra-European flights increased by 9 million tonnes in 2023 (+ 12 %) relative to 2022 ([1]). Improvements in ATM can contribute considerably to the mitigation of these emissions. Indeed, the ATM-related benefit pool for tackling CO_2 inefficiencies is estimated at around 9.3 % ([2]) for the European ATM network in general.

ATM itself is also impacted by climate change. Adverse weather caused by climate change is becoming a major cause of en-route capacity constraints in Europe, where the demand for mobility and air transport continues to grow. The proportion of commercial flights is expected to rise by 57 %, to approximately 16 million, in 2050 ([3]), even without considering new forms of air mobility (e.g. innovative air mobility (IAM), higher airspace operations). From 2035 onwards, zero-emission aircraft (e.g. hydrogen and electric) will enter into service. However, they are expected to carry fewer passengers than current aircraft; therefore, more flights will be required to move the same number of people.

Airspace will become more complex to manage with new types of air vehicles, such as drones, air taxis and high-altitude aircraft. This increasingly dense and complex mix of traffic will place extra pressure on ATM's capacity and its ability to provide the most environmentally efficient routes while maintaining safety as the paramount feature.

In addition, geopolitical crises, security threats and natural events all contribute to significant stress on air transport; today, the Russian war against Ukraine has reduced the airspace available for civil aviation in Europe by around 20 %.

All these factors call for a more scalable, resilient and efficient ATM system, leveraging digitalisation and automation to allow aircraft to fly optimal flight trajectories anywhere and at any time in the network. The cross-border nature of air transport and stringent safety and security requirements necessitate interoperable ATM systems and high levels of coordination between civil and military stakeholders.

Balancing these complex factors and objectives while maintaining Europe's competitive edge in the global air transport system is a formidable challenge that no single Member State, ATM organisation or operational stakeholder can tackle alone. Addressing this challenge requires a common vision for the future ATM system and a collective effort, involving all stakeholders, to achieve that vision. This is the objective of the Single European Sky (SES), of SESAR and of the European ATM Master Plan.

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[1] Eurocontrol, European Aviation Overview 2023.

[2] Eurocontrol, Performance Review Report 2023 – An Assessment of Air traffic Management in Europe.

[3] Eurocontrol, 'Aviation Outlook 2050: air traffic forecast shows aviation pathway to net zero CO_2 emissions'.

2.1 EU policy framework supporting the modernisation of air traffic management

In 2004, the EU established the SES initiative as a holistic framework aimed at harmonising and improving the performance of ATM in terms of safety, capacity, cost-efficiency and environmental impact. SES builds on five interrelated and interdependent pillars: economic aspects; airspace organisation/ network management; technological innovation; safety; and the human dimension (see Figure 1).

SES plays an important role in achieving the objectives of the European Green Deal and the EU's sustainable and smart mobility strategy ([4]), and together with other measures (e.g. RefuelEU ([5])) supports the green and digital transitions of the transport sector. The objectives of these twin transitions are to reduce emissions and to facilitate connectivity in a seamless and resilient multimodal transport network. This is crucial for reaching climate neutrality by 2050, as outlined by the long-term aspirational goal of the International Civil Aviation Organization (ICAO), and by the EU's ambition to reduce greenhouse gas emissions by at least 55 % by 2030 compared with 1990 levels. SES continues to contribute to the priorities set out in the European Commission's 2024–2029 political guidelines ([6]).

Changes in the SES policy framework are designed to make European airspace more efficient, cost-effective and environmentally friendly ([7]). The SESAR project is the technological innovation pillar of the SES and is an essential enabler of the other SES pillars (see Figure 1).

SESAR aims to deliver the Digital European Sky, a modern ATM system providing Europe with a high-performance, standardised and interoperable ATM infrastructure. SESAR is implemented through an ATM innovation cycle comprising definition, development and deployment phases.

- The definition phase refers to the long-term vision of the SESAR project, which is captured in the European ATM Master Plan. This plan provides the strategic direction and priorities for future development and deployment.
- The development phase covers research, development and validation activities aimed at delivering mature SESAR Solutions for deployment.
- The deployment phase covers the industrialisation of SESAR Solutions (e.g. standardisation, production and certification of ground and airborne equipment and processes necessary to implement SESAR Solutions) and their implementation (e.g. procurement, installation and putting into service of equipment and systems building on SESAR Solutions).

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[4] European Commission, Commission communication – Sustainable and Smart Mobility Strategy: putting European transport on track for the future (COM(2020) 789 final).

[5] Regulation (EU) 2023/2405 of the European Parliament and of the Council of 18 October 2023 on ensuring a level playing field for sustainable air transport, OJ L 2023/2405, 31.10.2023 (RefuelEU aviation). This regulation sets out the framework for the introduction of sustainable aviation fuels, the updating of the EU emissions trading system to complement the International Civil Aviation Organization's carbon offsetting and reduction scheme for international aviation.

[6] von der Leyen, U., Europe's Choice – Political guidelines for the next European Commission: 2024–2029. The relevant priority areas are 'a clean industrial deal', 'transport and digital connectivity', 'boost productivity with digital tech diffusion', 'put research and innovation at the heart of our economy', 'a new era for European defence and security', 'invest massively in our sustainable competitiveness' and 'tackle the skills and labour gaps'.

[7] Regulation (EU) 2024/2803 of the European Parliament and of the Council of 23 October 2024 on the implementation of the Single European Sky (recast).

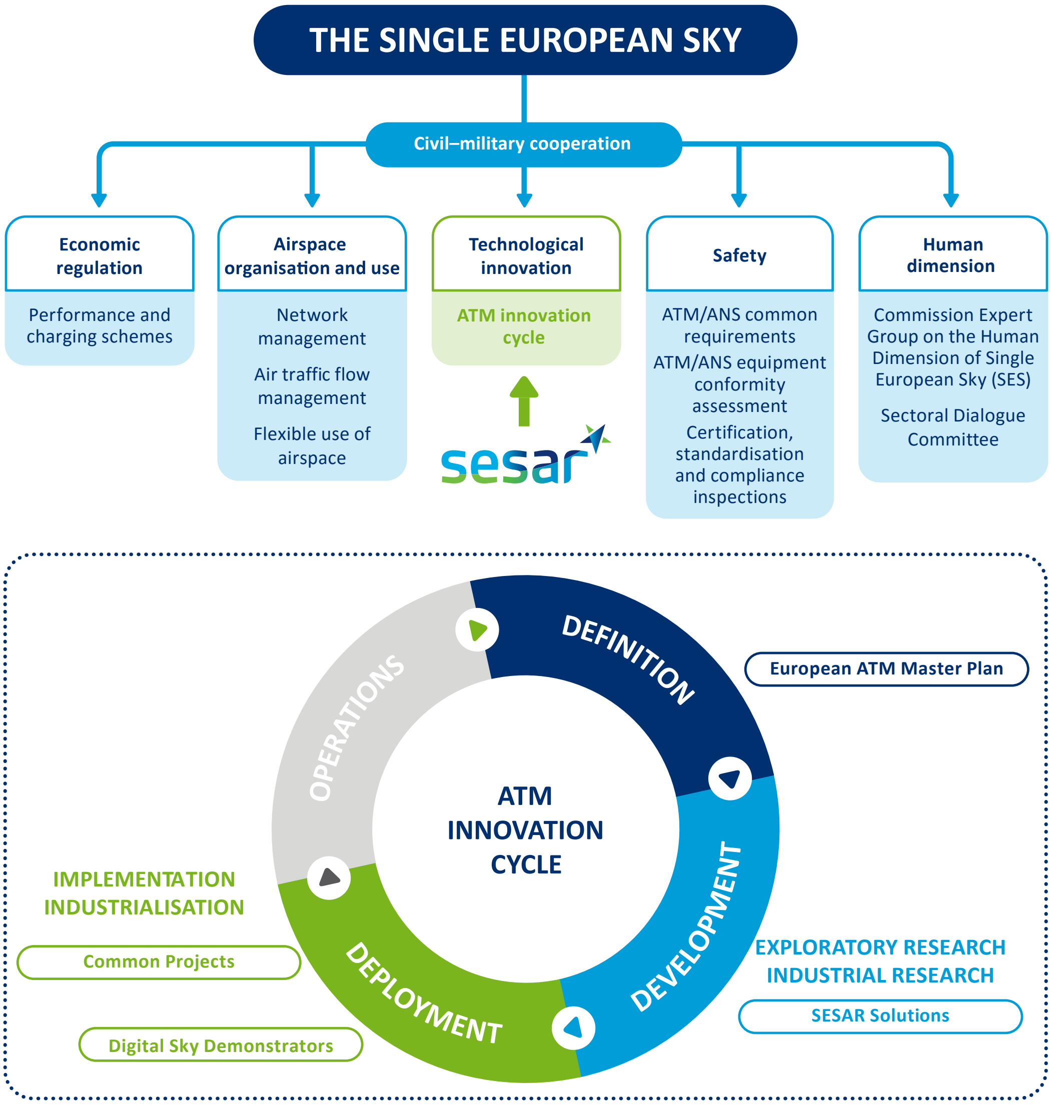

FIGURE 1: ATM INNOVATION CYCLE

The full effectiveness of SESAR relies on the coordination of the phases of the ATM innovation cycle.

The EU supports innovation in aviation through its research programme Horizon Europe (8), establishing the SESAR 3 Joint Undertaking (SESAR 3 JU) (9) to develop and deliver the Digital European Sky, and the Clean Aviation JU (10) to pave the way for the zero-emission aircraft of the future. The EU also supports the deployment of SESAR in the form of Digital Sky Demonstrators and Common Projects (11) through its infrastructure programme Connecting Europe Facility (12). Common Projects are coordinated by the EU-appointed SESAR Deployment Manager (13).

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8 Horizon Europe is the EU's key funding programme for research and innovation.

9 SESAR 3 JU.

10 Clean Aviation JU.

11 Commission Implementing Regulation (EU) 2021/116 of 1 February 2021 on the establishment of the Common Project One supporting the implementation of the European Air Traffic Management Master Plan provided for in Regulation (EC) No 550/2004 of the European Parliament and of the Council, amending Commission Implementing Regulation (EU) No 409/2013 and repealing Commission Implementing Regulation (EU) No 716/2014.

12 The Connecting Europe Facility is an EU funding instrument to promote growth, jobs and competitiveness through infrastructure investment at the European level.

13 SESAR Deployment Manager.

The green and digital transitions in the air transport sector require a collective and synergetic effort from stakeholders across the entire aviation sector. In this context, close civil–military collaboration in delivering the Digital European Sky is vital to the EU's future security and defence strategy in the air domain, ensuring the protection and effective use of the airspace (14).

The Digital European Sky covers the full geographical scope of the European Civil Aviation Conference (ECAC) area, and the underlying modernisation effort is closely coordinated and implemented by a wide range of individual operational stakeholders, air and ground systems manufacturers, professional staff, research bodies and many organisations representing stakeholders at the European level. The cooperative framework also involves institutional bodies such as the European Union Aviation Safety Agency (EASA); the European Organisation for the Safety of Air Navigation (EUROCONTROL), including the Network Manager (NM); the European Defence Agency; the European Organisation for Civil Aviation Equipment (EUROCAE); the SESAR 3 JU; and the SESAR Deployment Manager. Each one of these stakeholders plays an important role in the ATM innovation cycle. These roles are largely defined in EU legislation.The EU sees ATM modernisation as a global effort. Through cooperation with ICAO and partners in other regions of the world, Europe aims to maintain its technological and industrial leadership in aviation by shaping global standards and ensuring global interoperability and harmonisation. These efforts are vital prerequisites for safe, secure, efficient and sustainable global ATM.

2.2 Why is the European ATM Master Plan important?

The Master Plan sets out the vision for the Digital European Sky by 2045, the strategic deployment objectives (SDOs) to be implemented by 2035 and the development priorities (DPs) for the coming years expected to be implemented until 2045.

It therefore plays an important role in directing investments towards innovation priorities and planning for regulatory decision-making on ATM modernisation (15). Commonly agreed by all European ATM stakeholders, the Master Plan is the roadmap to make Europe the most efficient and environmentally friendly sky to fly in the world.

It is the key driver of the entire ATM innovation cycle in Europe and an important input for other strategic European documents, such as the European plan for aviation safety (EPAS) (16), the network strategy plan and the SESAR deployment programme, that will take due account of the Master Plan, as foreseen in the EU's regulatory framework.

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14 The EU's future security and defence strategy.

15 The Master Plan is also the main reference document for ATM modernisation efforts in a number of regulations (e.g. EASA, network functions, common projects, the performance and charging regulation).

16 EASA, European Plan for Aviation Safety (EPAS) 2024, 13th edition.

2.3 Why this update and what are the key changes?

The Master Plan requires regular updates to reflect evolving needs, emerging policy priorities or new constraints affecting the aviation ecosystem and ATM in particular.

This edition of the Master Plan aims to provide the SES, the SESAR project and its stakeholders with an effective tool to address the urgent challenges facing the sector. The plan is also a means of raising awareness among policymakers and the broader aviation community about the urgency of developing and deploying solutions to make ATM better performing, more sustainable, more interoperable and harmonised across Europe.

By endorsing this Master Plan, stakeholders, Member States and SES bodies, represented in the SESAR 3 JU Governing Board, signal their commitment to collectively working to achieve the Digital European Sky.

This edition of the Master Plan has been streamlined in order to make it a strategic steering tool, focusing on 'why act now' (link to policy and performance ambitions), 'what needs to be done' (vision with a clear sense of priorities) and 'by when' (high-level roll-out to achieve the vision).

The intention is to better serve the needs of decision-makers at public and private executive levels. In parallel, a revised reporting and monitoring framework, already adopted by the SESAR 3 JU Governing Board, enables greater transparency and improved monitoring.

In terms of content, the main changes include the following:

- The Master Plan reimagines Europe's aviation infrastructure to support the decarbonisation of air transport while keeping safety as the paramount feature. Its aim is to make Europe the most efficient and environmentally friendly sky to fly in the world, reflecting the commitment of the aviation sector to becoming carbon-neutral by 2050 and thereby contributing to the EU's policy ambition in this regard. It is estimated that improvements to ATM operations **could reduce CO_2 emissions by up to 6 %**. For the first time, the transformation of ATM is placed in the context of the planned introduction of sustainable aviation fuels (SAFs) and the expected entry into service of zero-emission aircraft.
- The Master Plan forms the strategic basis for supporting investment decisions and facilitating the early planning of industrialisation activities. The plan outlines 10 strategic deployment objectives (SDOs) that need to be implemented between 2025 and 2035. These SDOs build on the 137 SESAR solutions ([17]) that are already available for deployment. By aligning the SDOs with investment planning by air navigation service providers (ANSPs) in the SES performance and charging scheme, the Master Plan aims to accelerate market uptake by a critical mass of early movers.

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[17] SESAR 3 JU, Digital SESAR Solutions Catalogue.

- The Master Plan also defines 12 research priorities for phase D, 'Digital European Sky' – an exercise not done in previous editions. These priorities address new development challenges and expectations for SESAR that were not foreseen earlier, such as the vision of making Europe the most efficient and environmentally friendly sky to fly in the world; the integration of IAM, higher airspace operations and next-generation aircraft for zero-/low-emission aviation by 2035; as well as a new security and defence context for ATM in Europe. In 2025, the SESAR 3 JU will launch calls for exploratory and industrial research to implement these priorities and to make considerable progress on phase D research by 2030.
- The Master Plan puts a greater focus on security and cybersecurity matters in light of the evolving security and defence context in Europe (18), including the unavailability of airspace due to the Russian war against Ukraine, a significant increase in cyberattacks and global navigation satellite system (GNSS) jamming and spoofing. The Master Plan underlines the importance of enhanced civil–military cooperation in increasing the resilience and flexibility of European airspace.
- The Master Plan provides strong support for the transition to a modern, data-driven and cloud-based service-oriented architecture (SOA) delivery model. This new approach will enable the quicker deployment of new features and improvements while ensuring the interoperability of operations, airspace and technology across ANSPs, airports and airspace users. Moreover, the transition to the new service delivery model will facilitate the development of a technical regulatory framework for future ATM in Europe. Rather than overhauling and certifying the entire system, this future-proof framework will enable the development or updating of specific services to meet new standards. In doing so, the framework will be better aligned with best practices applied in other safety- and security-critical sectors. This approach has already been supported by major European ATM stakeholders in a joint statement calling for a new service delivery model (19).

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18 See the Council conclusions on EU security and defence, adopted on 27 May 2024.
19 SESAR 3 JU, 'Call to action! Transition to new service delivery model for European air traffic management'.

- The Master Plan addresses the changing aviation landscape with the arrival of new vehicles (e.g. drones, air taxis, new military combat systems, new low- and zero-emission aircraft, higher air space operations, space traffic transiting airspace), in order to unlock the value at stake of innovative mobility services in Europe. This edition of the Master Plan defines how ATM can become more agile to accommodate this changing environment.
- The Master Plan envisages an evolved role for humans in ATM through dynamic human–machine teaming and greater levels of automation. It aligns SESAR's automation strategy and EASA's artificial intelligence 2.0 roadmap ([20]) to strengthen this ambition.

2.4 Structure of the Master Plan

The **Vision** describes where the sector wants to be by 2045, our performance ambition, and the levers that will bring about the transformation.

The **Roll-out** provides the current state of play in terms of the development and deployment of SESAR solutions, and the timeline for the full roll-out of the vision in four phases (A–D).

The **Deployment priorities** detail the new SDOs to ensure the relevant SESAR Solutions are deployed, including a new service delivery model.

The **Development priorities** describe the industrial and exploratory research activities required for delivering solutions in line with the vision and performance ambitions.

The **Benefits, investment needs and risks** outline the expected benefits (in terms of capacity, fuel, CO_2 emissions, punctuality and cost-efficiency), the investment needs, and the associated risks and mitigation measures across the ECAC area, and what they mean for Europe's economy and citizens.

The **Roadmaps** in the Appendix provide timelines for the development and deployment activities that have been prioritised in the following key areas: trajectory-based operations (TBO); communication, navigation and surveillance (CNS); automation; U-space 2.0; civil–military capabilities; and cybersecurity.

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[20] EASA, Artificial Intelligence Roadmap 2.0: Human-centric approach to AI in aviation.

3. Vision

This chapter sets out the vision for 2045: to make Europe the most efficient and environmentally friendly sky to fly in the world. It begins by describing what this reality might look like and goes on to detail the performance ambitions that drive the vision, showing how an even stronger emphasis on digitalisation is the only way to achieve it.

3.1 Digital European Sky vision – Making Europe the most efficient and environmentally friendly sky to fly in the world

It is 2045 and European air traffic management is fully integrated into a multimodal transport system (including IAM solutions such as air taxis), enabling passengers to move seamlessly from door to door, safely reaching their destination on time, with the lowest environmental footprint possible. All flights/missions (crewed or uncrewed) operate in a way that maximises, to the fullest extent, aircraft capabilities to reduce the overall climate impact of aviation (in terms of CO_2 and non-CO_2 emissions). ATM processes and services optimise each flight trajectory considering the individual performance characteristics of each aircraft, user preferences, real-time traffic, local circumstances and meteorological conditions throughout the network. Trajectory optimisation is systematic, continuous and extremely precise. Potential conflicts between trajectories or traffic bottlenecks are resolved much earlier than in the past, bringing safety benefits. Passengers know that when they take a flight their environmental footprint will be as low as it can be, and that there will be no time wasted in the air or on the ground during their journey.

This transformation is possible thanks to the implementation of a new (service-oriented and cloud-based) service delivery model in which service providers can dynamically and collaboratively scale capacity up or down in line with demand from all airspace users. These capacity adjustments are implemented in real time and ensure optimal and efficient dual (both civil and military) use of resources at any moment across the network (airspace, data, infrastructure and human–machine teaming).

The continuous optimisation of every flight/mission from gate to gate is systematically guaranteed thanks to high connectivity between air–ground and ground–ground components. Each aircraft ([21]) is continuously connected and sharing its trajectory with a highly automated traffic management system (one single trajectory reference is agreed and shared across all actors involved on the ground and in the air). For certain phases of flight, the system is fully automated and able to handle both nominal and non-nominal situations.

In this new environment, the role of the human has significantly evolved, performing only the tasks that are too complex for automation to handle, teaming up with automation to address increasing traffic complexity. Voice communication is no longer the primary way of communicating as most routine tasks are managed through machine-to-machine applications. Large volumes of data flow securely and effectively between trusted users, enhancing the ability not only to optimise processes but also to detect, mitigate and respond to new threats. In doing so, ATM always remains resilient and adaptable to evolving security dynamics.

The design and the ability of the European ATM system to harness the full potential of digital technologies – enhancing safety, security and sustainability – has become so evident that, globally, all stakeholders have decided to adopt this model.

3.2 Performance ambition

The vision is driven by the need to improve ATM in key performance areas (see Figure 2) in line with the SES performance framework ([22]), covering safety, the environment, capacity and cost-efficiency. These areas are complemented by additional performance areas, described in this section.

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[21] Refers to civilian and state aircraft when interoperable, considering that the military aim to fulfil their missions while ensuring civil aviation safety and considering their environmental impact.

[22] 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.

While these performance areas are complementary and interdependent, it is widely acknowledged that to achieve much higher levels of environmental performance the ATM system will need to be designed to handle significantly more capacity than it does today.

Accordingly, the future ATM system should be designed to:

- continuously improve **safety** levels as traffic increases and becomes more complex to manage;
- avoid any negative climate impact due to ATM on the ground and in the air (**sustainability**) – as the challenge to achieve climate neutrality goes beyond CO_2 emissions, the future design of the system should be able to adapt to minimise the total impact of aviation on the climate, while addressing noise and local air quality;
- help transform the way **capacity** is delivered, enabling service providers to dynamically and collaboratively scale capacity up or down (**scalability and resilience**) in line with all demand (both civil and military, and crewed and uncrewed) – these capacity adjustments should be implemented within minutes and ensure the optimal and cost-effective use of resources (airspace, data, infrastructure and human–machine teaming) at any moment;
- ensure that data flows effectively and securely between trusted users (**security**);
- address evolving security and defence needs, providing flexibility within a civil–military ATM environment (**security and defence**) ([23]);
- improve the overall **passenger experience**.

To achieve optimal performance, improvements should also be made in the following areas:

- **Predictability** ensures that flights follow expected patterns and schedules.
- **Punctuality** relates to the timing of departures and arrivals.
- **Cost-efficiency** refers to optimum resource allocation, productivity and the effective use of technologies and rationalisation (e.g. infrastructure).

FIGURE 2: PERFORMANCE AREAS IN SUPPORT OF OVERALL PASSENGER EXPERIENCE

See Chapter 7 for details of the expected performance benefits.

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[23] See the civil–military capabilities roadmap in Section A.5.

3.3 Key transformation levers

Delivering the vision and its associated performance ambition will require a strong focus on five key transformation levers (see Figure 3), as well as the use of various tools, policy measures and the full collaboration of involved aviation stakeholders.

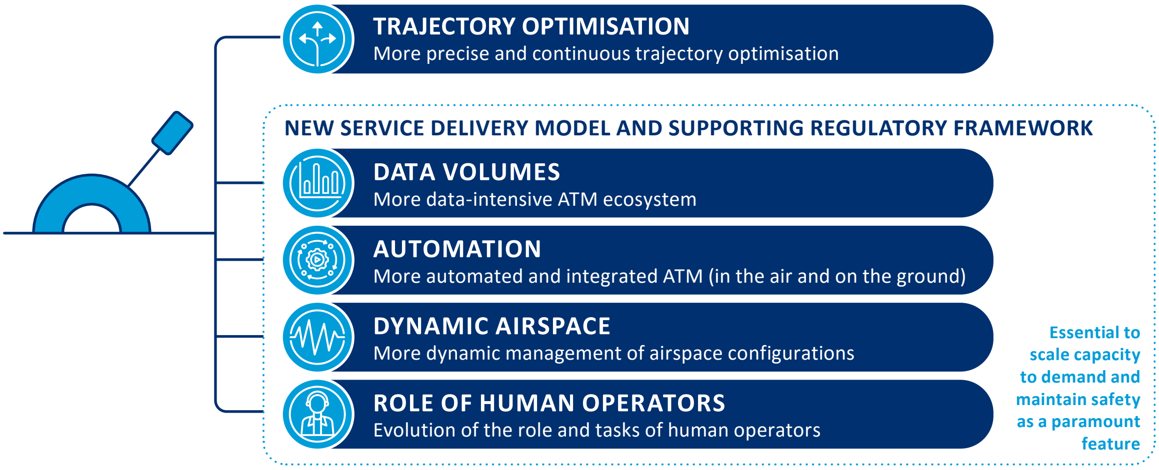

FIGURE 3: TRANSFORMATION LEVERS

3.3.1 Trajectory optimisation

The skies of tomorrow will be more diverse. Electric and hydrogen aircraft, large remotely piloted, uncrewed and autonomous aircraft and high-altitude vehicles will enter the mix of operations, and the needs of the military will evolve. Guaranteeing systematic, continuous and precise optimisation of all aircraft trajectories throughout their life cycle, from planning to execution, from gate to gate, and within congested airspace, is only possible with trajectory-based operations (TBO).

See Section A.1 for the TBO roadmap.

3.3.2 Data volumes

Trajectory optimisation will require the collection, secure transfer and processing of large volumes of data, including individual aircraft performance characteristics, user preferences, real-time traffic information and meteorological conditions, throughout the network. Increased real-time sharing of secure and trusted data will enable airborne and ground systems and actors to stay interconnected and share relevant collective situational awareness.

3.3.3 Automation

Higher levels of automation will be introduced in the air and on the ground in the form of advanced digital tools (in some cases using AI) to deal safely with complex decision-making while increasing capacity and environmental performance. This increased automation will require the teaming up of human operators and systems (i.e. human–machine teaming) to make best use of the large volumes of data to optimise trajectories.

See Section A.3, which defines the automation roadmap. This roadmap includes a framework for categorising the levels of automation, ensuring alignment with EASA's artificial intelligence roadmap 2.0 ([24]).

3.3.4 Dynamic airspace

Dynamic airspace will enable a near real-time configuration of the airspace, with human operators and systems teaming up to meet the needs of all airspace users (civil and military) and to manage capacity more efficiently.

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[24] EASA, Artificial Intelligence Roadmap 2.0: Human-centric approach to AI in aviation.

For certain phases of flight, the system will be fully automated and able to handle both nominal and non-nominal situations. Airspace configuration, which today is designed to minimise complexity for human operators, will become more dynamic in near real-time.

3.3.5 Role and function of human operators

The teaming up of human operators and systems (i.e. human–machine teaming) will result in a gradual evolution of the role and skills of human operators (e.g. air traffic controllers, air traffic safety electronics personnel, flight crew and operators), as well as the emergence of new roles. A robust and resilient ATM system will empower humans to act flexibly especially in non-nominal situations.

See Section A.3 for details of the automation roadmap and human–machine teaming.

3.4 New service delivery model and supporting regulatory framework

Until now, the ATM service delivery model has typically evolved every 10 to 20 years through major upgrades to the core ATM system. To facilitate deeper and faster changes across the five transformation levers, the model will be replaced by a data-driven and cloud-based service-oriented architecture for all operational environments.

The new service delivery model has already gained the support of ANSPs and manufacturers, as illustrated by the signing of a joint statement of commitment in June 2024, available at www.sesarju.eu/servicedelivery.

The new service delivery model will enhance flexibility, scalability, resilience and innovation through its service-oriented design, with open and standardised interfaces based on application programming interface technologies. This architecture will enable faster innovation, a higher degree of automation and seamless integration of new services, through:

- open ATM patterns enabling the integration of components provided by various system providers to facilitate multi-vendor solutions using open platforms and interfaces;
- decoupling of service and infrastructure layers through cloud computing (including the various system components);
- a cloud-native architecture of components with standardised and open interfaces that can be deployed on commodity cloud technologies.

The approach will also facilitate data exchange and enable the quicker deployment of new features, advancing human–machine interactions while ensuring interoperability in operations, airspace and technology across multiple service providers. In addition, it will ensure that civil ANSPs can handle information relevant to national security, such as data on military operational flights, without any risk of disclosure to unauthorised parties.

Furthermore, the transition to service-oriented architecture will facilitate the development of a future-proof EASA regulatory framework for ATM in Europe. Rather than overhauling and certifying an entire system, this framework will enable the development or updating of specific services to meet new standards. In doing so, it will be better aligned with best practices applied in other safety- and security-critical sectors.

3.4.1 Transition to the new service delivery model

The implementation of this new service delivery model represents a significant evolution for a typical area control centre (ACC) (25), which today relies primarily on on-site infrastructure, consisting of servers with dedicated hardware and on-premises software deployments. The infrastructure of tomorrow's ACC will be far more versatile, incorporating both on-premises components and leveraging various cloud types (i.e. private, public and hybrid).

This new architecture will support multiple deployment models, including infrastructure as a service (IaaS), platform as a service (PaaS), software as a service (SaaS) and cloud-based business services (backend as a service - BaaS). This evolution will enable ACCs to scale their service delivery more efficiently, integrate new technologies seamlessly and benefit from faster innovation. The new model will also increase resilience, as it will enable the operation of services from different locations and dynamically switch locations in case of local system disruptions (as illustrated in Figure 4).

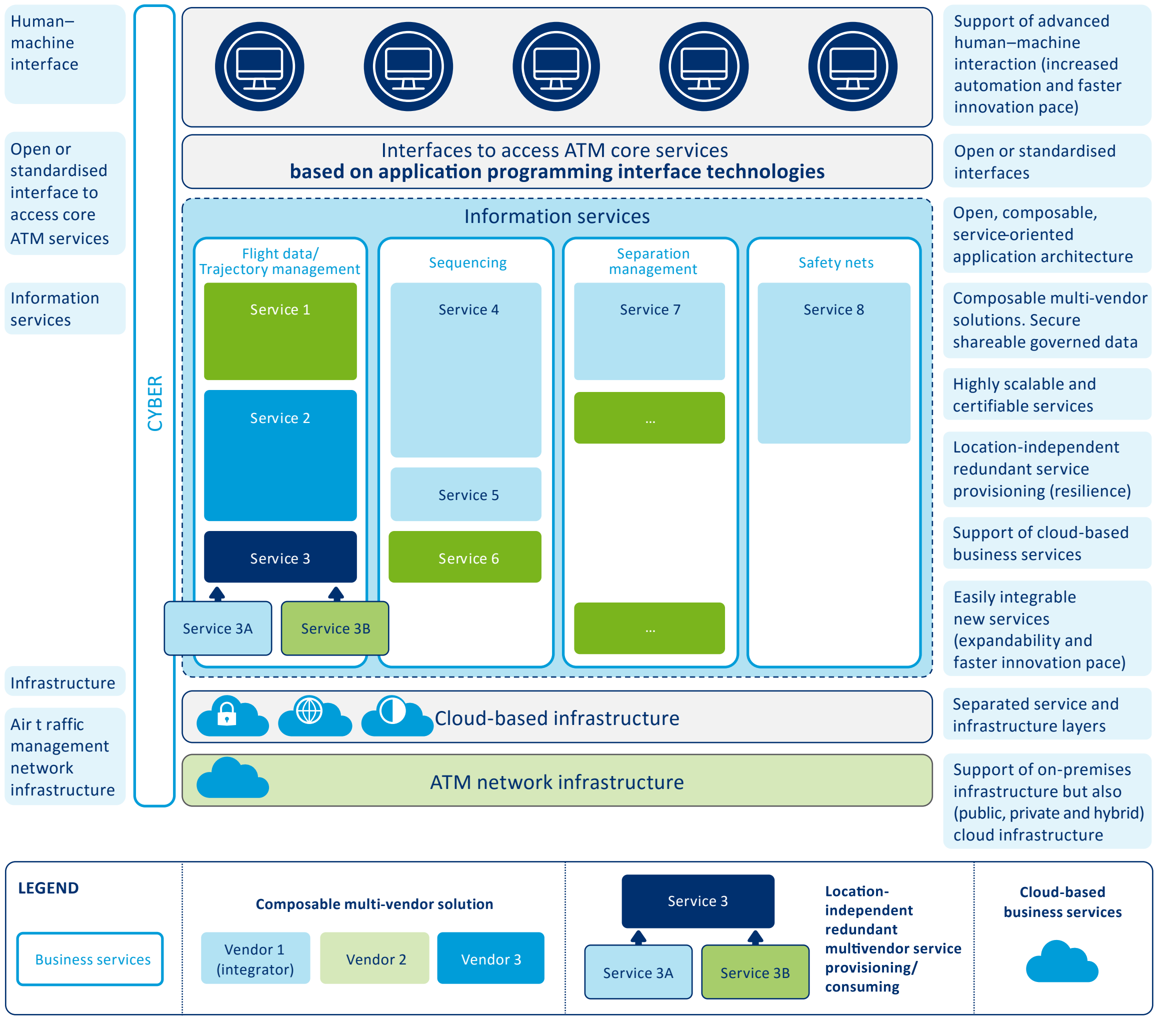

FIGURE 4: VISUALISATION OF THE NEW SERVICE DELIVERY MODEL FOR A TYPICAL ACC

A breakdown of the different business services enabled by the new service delivery model for a typical ACC is available in Section A.7.

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25 The new service delivery model will also impact approach and towers.

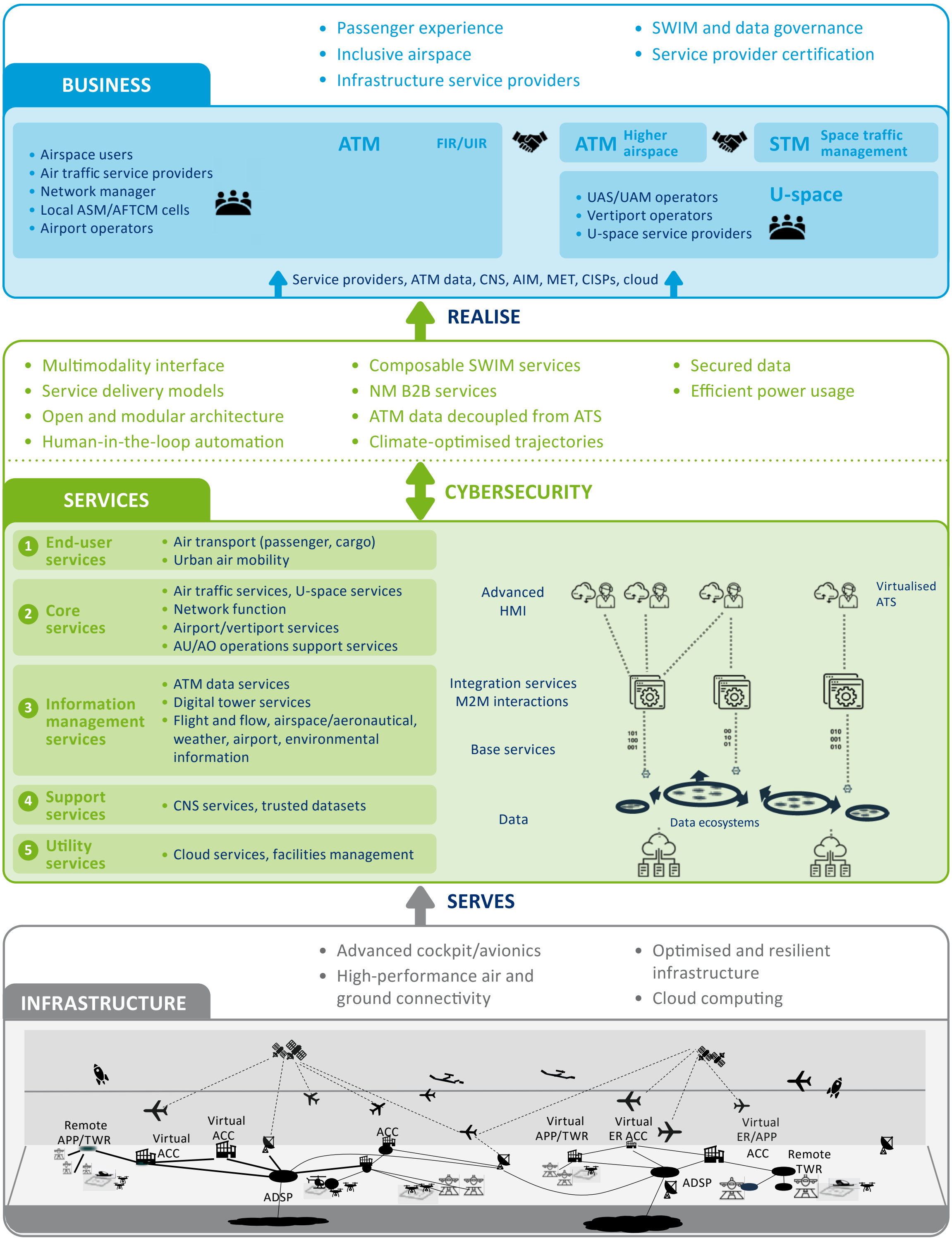
3.4.2 A layered approach to service delivery

The transition affects not just individual ACCs but the entire ATM system, focusing on three main layers of service delivery (as illustrated in Figure 5): business, services and infrastructure.

- The **business** layer captures the business goals, processes, functions and organisational arrangements of all stakeholders concerned, including new entrants (i.e. airspace users, air traffic service (ATS) providers, Network Manager, local airspace management and air traffic flow and capacity management cells, airport operators, uncrewed aircraft systems (UAS), IAM operators, vertiport operators and related U-space service providers delivering drone/UAS traffic management). This layer also describes an open-market ecosystem for service delivery and the specific roles, responsibilities and capabilities of each of these stakeholders.
- The **services** layer outlines the future service landscape in a data-driven architecture. This layer is organised along four service domains:
    - **End user** services cover air transport services for passengers and cargo, and interfaces with other modes of transport within an innovative multimodal mobility framework. These services aim to deliver a high-quality passenger experience.
    - **Core** services refer to ATM and U-space air traffic management services and functionalities in a highly inclusive and dynamic airspace. These services are critical for improving safety, cybersecurity, capacity, operational efficiency and sustainability against a backdrop of traffic growth and increasing traffic complexity and diversity.
    - **Information management** services provide accredited, quality-assured and timely information exchange between all stakeholders to support the core services on flight and flow, airspace, weather (meteorology (MET)) and environmental information. These services are essential to enabling scalable and flexible ATM and U-space service provision.
    - **Support and utility** services provide access to communication, navigation and surveillance (CNS) services, system-wide information management (SWIM) infrastructure and IT services (including cloud-based services). These services contribute to secure, resilient and cost-efficient operations. See Section A.2 for the CNS roadmap.
- The **infrastructure** layer refers to technology and infrastructure systems, such as ground and airborne systems, MET sensors, CNS, system-wide information management, IT (including cloud-based) infrastructure and ATM network infrastructure such as the pan-European network service (PENS) or more broadly speaking the network infrastructure provided by the designated Network Manager. This layer is closely interconnected with other layers in the architecture, ensuring alignment between technology and business goals, and providing the necessary resources. It contributes to reducing the impact of ATM on the climate through virtualisation (e.g. virtual centres, remote towers), rationalisation, cloud computing and adoption of new power supply technologies. Within this layer, civil–military dual-use technologies, in particular in the domain of CNS, enable greater interoperability, optimise the use of radio spectrum and increase the economic and environmental sustainability performance. See Section A.2 for the CNS roadmap.

Development and deployment activities have been carried out on the service delivery model. See Section 4.2 for the current state of play.

The architecture is part of priority setting for future development and deployment. More details are provided in Chapters 5 and 6, alongside roadmaps in the Appendix.



BUSINESS

- Passenger experience
- Inclusive airspace
- Infrastructure service providers
- SWIM and data governance
- Service provider certification

ATM **FIR/UIR**

- Airspace users
- Air traffic service providers
- Network manager
- Local ASM/AFTCM cells
- Airport operators

ATM **Higher airspace**

STM **Space traffic management**

U-space

- UAS/UAM operators
- Vertiport operators
- U-space service providers

Service providers, ATM data, CNS, AIM, MET, CISPs, cloud

REALISE

- Multimodality interface
- Service delivery models
- Open and modular architecture
- Human-in-the-loop automation
- Composable SWIM services
- NM B2B services
- ATM data decoupled from ATS
- Climate-optimised trajectories
- Secured data
- Efficient power usage

CYBERSECURITY

SERVICES

① End-user services	Air transport (passenger, cargo) Urban air mobility
② Core services	Air traffic services, U-space services Network function Airport/vertiport services AU/AO operations support services
③ Information management services	ATM data services Digital tower services Flight and flow, airspace/aeronautical, weather, airport, environmental information
④ Support services	CNS services, trusted datasets
⑤ Utility services	Cloud services, facilities management

SERVES

INFRASTRUCTURE

- Advanced cockpit/avionics
- High-performance air and ground connectivity
- Optimised and resilient infrastructure
- Cloud computing

FIGURE 5: TARGET ENTERPRISE ARCHITECTURE (26)

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26 ADSP, ATM data service provider; AIM, aeronautical information management; AO, airport operator; APP, approach; ASM, airspace management; ATFCM, air traffic flow and capacity management; AU, airspace user; B2B, business-to-business; CISP, common information service provider; FIR, flight information region; HMI, human–machine interaction; M2M, machine–machine; STM, space traffic management; SWIM, system-wide information management; TWR, tower; UAM, urban air mobility; UIR, upper information region.

3.5 Enabling new forms of mobility and uses of the sky

As described in Section 3.1, the aim is to enable the market uptake of innovative air mobility (27) solutions covering new forms of air mobility, initially through crewed vertical take-off and landing (VTOL)-capable aircraft (VCA) operations.

Aligned with the European Commission's drone strategy 2.0 (28), U-space 2.0 (see Figure 6) refers to the next evolution of U-space to fully integrate drone and ATM operations to support the scaling up of IAM and services. U-space 2.0 enables increased uncrewed aircraft traffic and is a move towards the integration of crewed and uncrewed aircraft into the same airspace.

Other airspace users, such as general aviation (GA) and rotorcraft, will obtain operational and safety benefits thanks to interoperability and seamless information sharing between all airspace users.

U-space foundation services (U1) and initial services (U2) are already being rolled out. Meanwhile, advanced services (U3) and full services (U4) require further development activities to secure an increased degree of integration between ATM and U-space services.

See Section A.4 for the U-space 2.0 roadmap.

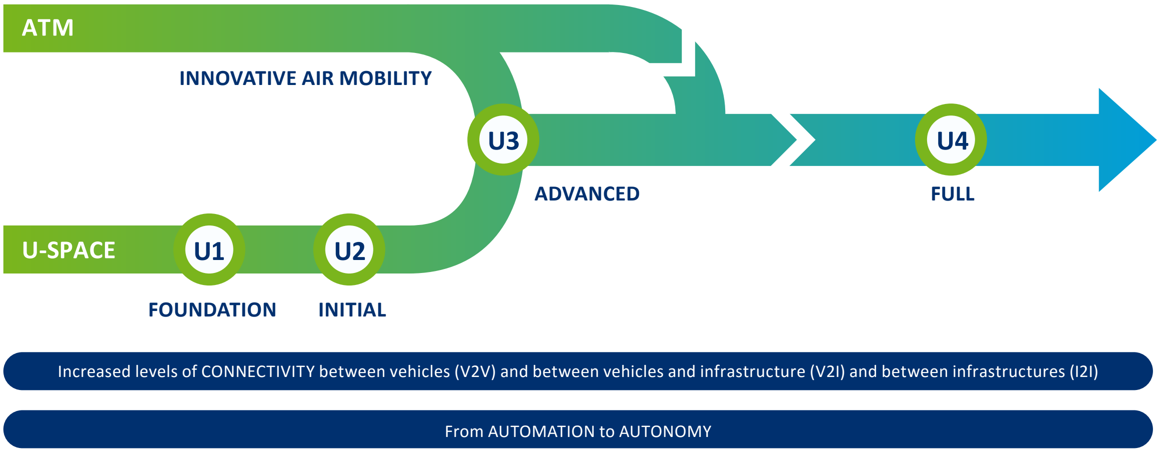

FIGURE 6: U-SPACE 2.0 IN THE CONTEXT OF THE OVERALL ATM EVOLUTION

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27 According to the European drone strategy 2.0, the concept of IAM includes operations with novel aircraft designs (aircraft that do not automatically fall under one of the known categories, but that have vertical take-off and landing capabilities, have specific (distributed) propulsion features, can be operated in an uncrewed configuration, etc.) that are conceived to offer a new type of air mobility for people and cargo, in particular in congested (urban) areas, based on integrated air- and ground-based infrastructure.

28 European Commission, Commission communication – A Drone Strategy 2.0 for a Smart and Sustainable Unmanned Aircraft Eco-system in Europe (COM(2022) 652 final).

3.6 Collective action on security aspects enabling dual use of technologies

New threats demand greater resilience and an increased security posture in ATM. Recent geopolitical unrest, for example, has created a multifaceted crisis for European ATM, combining operational, economic and logistical challenges that will continue to shape the landscape of European aviation for years to come. As a result, military airspace requirements are growing and also the need for dual-use technologies that serve both civil and military applications, and that optimise the utilisation of the airspace for all. The vision therefore includes elements such as advanced flexible use of airspace and the integration of remotely piloted aircraft systems (RPAS), but also leverages dual-use technologies such as artificial intelligence (AI) and advanced CNS systems to enhance both civil and military air traffic operations.

Airspace configuration and management will be fully dynamic to deliver the right capacity at the right time, supported by dynamic civil–military collaborative decision-making, irrespective of air traffic controllers' physical locations. RPAS will fly safely in all classes of airspace, sharing it with crewed aviation and other airspace users, and will be integrated into airport operations. Civil and military stakeholders will share plans, decisions and updates through a system-wide information management (SWIM) technology solution.

See Section A.5 for the civil–military roadmap.

Cyberattacks are increasing in frequency and sophistication, calling for ongoing vigilance, a proactive approach to data security and the development of further enhanced technologies to protect the future ATM system, which will be more data-driven, open to trusted users, connected and interdependent.

See Section A.6 for the cybersecurity capabilities roadmap.

For both aspects, the Master Plan will be key to feed into upcoming defence-related EU activities such as the EU airspace strategy for security and defence.

4. Roll-out

This chapter describes the critical path and the overall timeline for ensuring a smooth transition from today's ATM system to tomorrow's Digital European Sky. It also provides an update on the status of development and deployment activities, and establishes the conditions that will determine the successful roll-out of the vision by 2045.

4.1 Roll-out in four phases

The roll-out is divided into four overlapping phases:

- **Phase A** addresses known critical network performance deficiencies by enhancing collaboration between stakeholders, including across state borders and with aircraft, implementing initial system-wide information management (SWIM) and introducing initial network capacity and demand balancing measures. Deployment is to be completed by 2025.
- **Phase B** delivers efficient services and infrastructure through the launch of initial ATM data services, the introduction of cross-border free-route operations and the integration of advanced airport performance management in the network. Deployment is under way and will be completed by 2030.
- **Phase C** defragments 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. Development for this phase is near completion and deployment is under way, with completion expected by 2035.
- **Phase D** achieves the Digital European Sky. It aims to make Europe the most efficient and environmentally friendly sky to fly in the world by delivering a fully scalable system for crewed and uncrewed aviation, supported by a digital ecosystem, full air–ground system integration, distributed data services and high levels of automation and connectivity. Development for this phase has started and deployment should be completed by 2045.

Figure 7 illustrates the deployment across the four phases, in line with the aim of completing deployment by 2045.

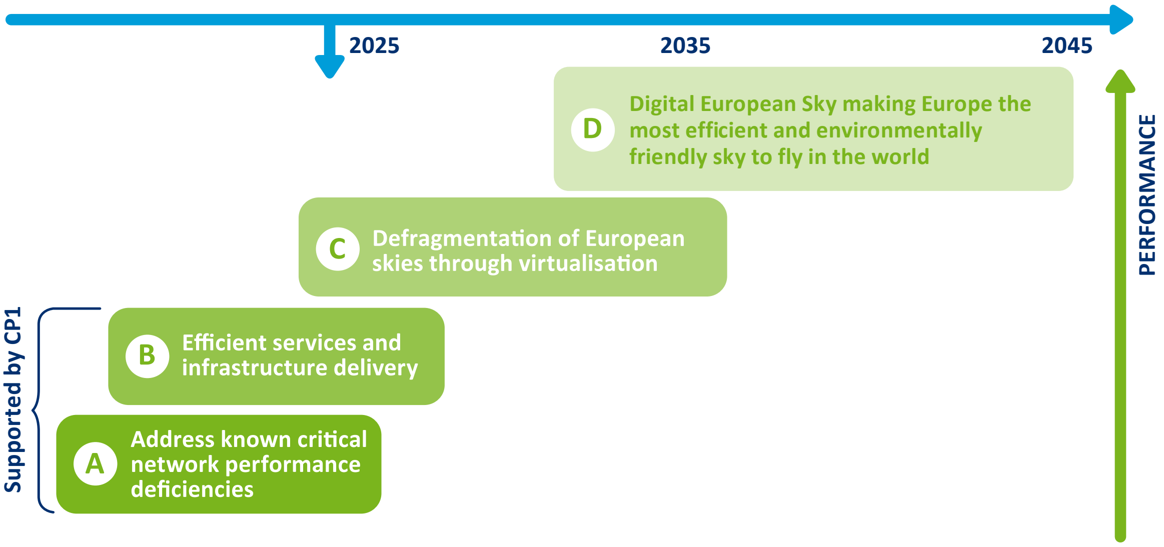

FIGURE 7: FOUR-PHASED APPROACH TO ROLL-OUT (29)

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29 Commission Implementing Regulation (EU) 2021/116 of 1 February 2021 on the establishment of the common project one supporting the implementation of the European Air Traffic Management Master Plan provided for in Regulation (EC) No 550/2004 of the European Parliament and of the Council, amending Commission Implementing Regulation (EU) No 409/2013 and repealing Commission Implementing Regulation (EU) No 716/2014, OJ L 36, 2.2.2021, p. 10.

4.2 Current state of play

The ATM innovation life cycle covers SESAR definition (European ATM Master Plan), development (exploratory and industrial research) and deployment (industrialisation and implementation). This chapter provides the current state of play in the development and deployment activities plotted against the four phases of the roll-out of SESAR Solutions to achieve the Digital European Sky.

4.2.1 Status of SESAR development

As illustrated in Figure 8, SESAR development has been completed for phases A and B. For phase C, 66 % of development activities are complete and the remainder will be completed by 2026. Phase D activities have started ([30]).

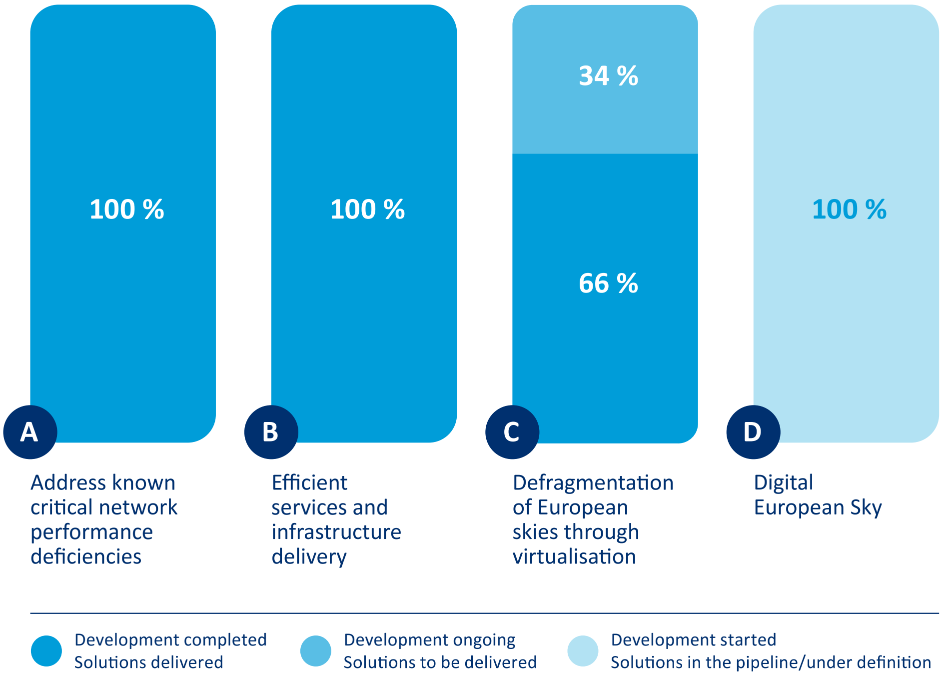

FIGURE 8: STATUS OF SESAR DEVELOPMENT

4.2.2 Status of SESAR deployment

Out of the SESAR Solutions available for deployment, for phase A, 83 % are being rolled out and standardisation work is under way for an additional 9 % (see Figure 9). For phase B, 61 % are being rolled out and standardisation work is under way for an additional 28 %. For phase C, 8 % of available solutions are being rolled out and standardisation work is under way for an additional 79 %.

It should be noted that for all three phases additional efforts are needed to encourage the full market uptake of the available solutions ([31]).

Deployment actions building on these solutions have been prioritised. They will therefore constitute the next wave of deployments as reflected in Chapter 5. The SDOs listed there will deliver phase C by 2035.

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[30] See SESAR 3 JU, Strategic Development Monitoring Report.

[31] See SESAR 3 JU, Strategic Deployment Monitoring Report.

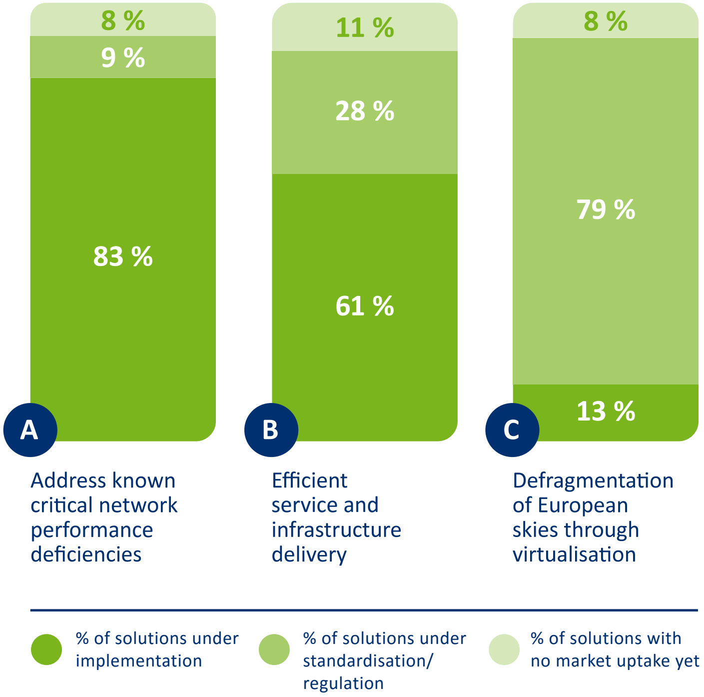

FIGURE 9: STATUS OF SESAR DEPLOYMENT

Solutions in phases A–C are projected to deliver the following performance benefits compared with the 2012 baseline (32), while maintaining or, where possible, improving safety levels:

- punctuality (+ 19 %),
- cost-efficiency (+ 30.3 %),
- airport capacity (+ 23 %),
- en-route capacity (+ 59.7 %),
- terminal manoeuvring area (TMA) capacity (+ 36 %),
- reduction of CO_2 emissions thanks to fuel efficiency (– 3.4 %),
- reduction of additional flight time (– 41 %).

4.3 Critical path and key milestones to roll out the Digital European Sky by 2045

This section defines the critical path for establishing the Digital European Sky by 2045 so that Europe can become the most efficient and environmentally friendly sky to fly in the world. It puts the transformation of ATM into perspective with the planned introduction of SAF (33) and the next generation of aircraft for zero-emission aviation (34).

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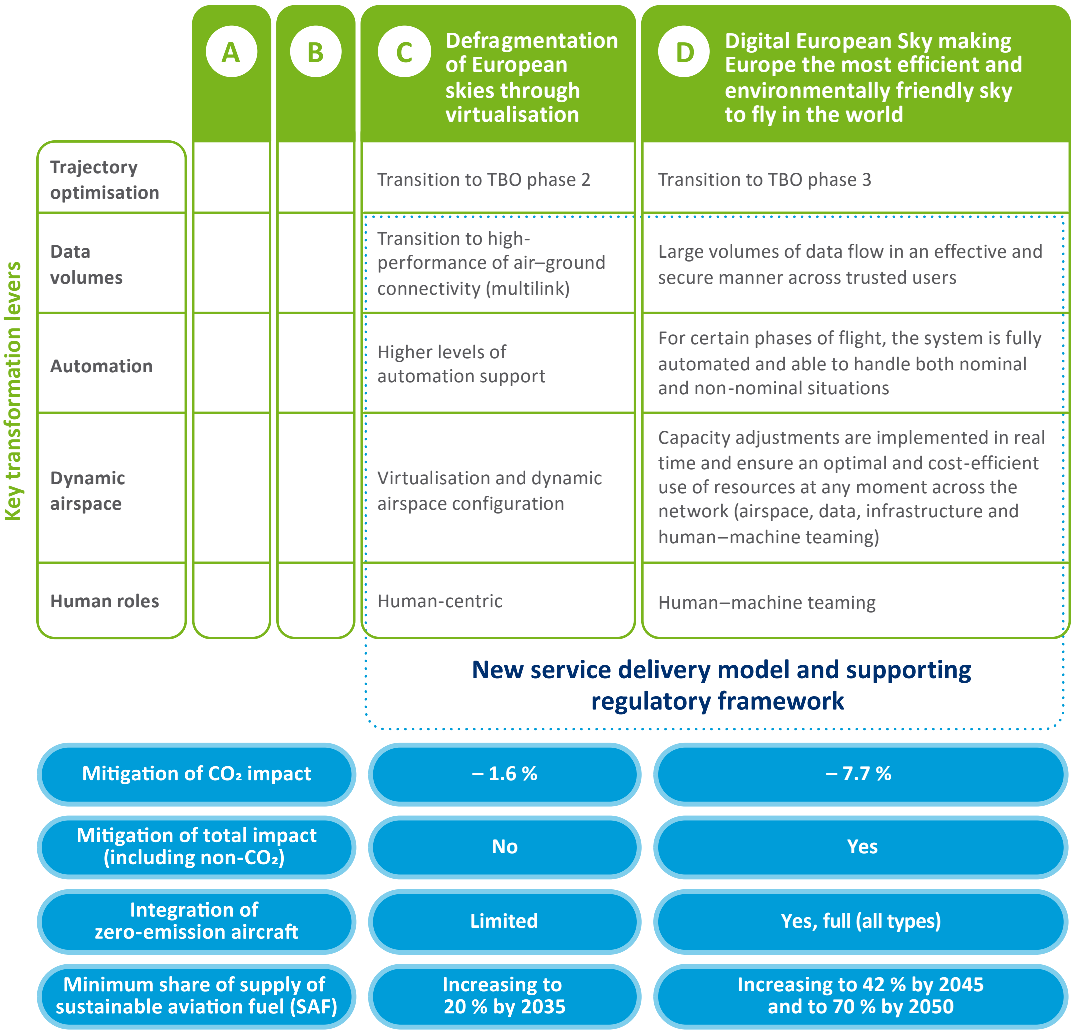
32 The baseline year for the 2020 edition of the European ATM Master Plan was 2012; see SESAR 3 JU, SESAR 2020 Closure Report

33 ReFuelEU aviation promotes the increased use of SAFs. This measure is implemented as part of the ‘fit for 55’ package to meet the emission reduction target of 55 % by 2030. The regulation sets out requirements for aviation fuel suppliers to gradually increase the share of SAFs in the conventional aviation fuel supplied to EU airports.

34 The Alliance for Zero-Emission Aviation’s vision on enabling hydrogen and electricity-powered flights in Europe sets out the ambitious objective of having 36–68 % of intra-EU flights operated by hydrogen- and electricity-powered aircraft by 2050, and describes how these aircraft would progressively enter and expand in the market from 2035.

The critical path looks beyond completing Common Project 1 (CP1) (35) at the key transformations needed to secure the transition to TBO. Figure 10 identifies these elements and their impact on the environment for each technology lever across phases C and D.

The Appendix provides further details of the critical pathways for specific ATM domains (TBO, CNS, automation, U-space, civil–military and cybersecurity).



Key transformation levers

	A	B	C Defragmentation of European skies through virtualisation	D Digital European Sky making Europe the most efficient and environmentally friendly sky to fly in the world
Trajectory optimisation			Transition to TBO phase 2	Transition to TBO phase 3
Data volumes			Transition to high-performance of air–ground connectivity (multilink)	Large volumes of data flow in an effective and secure manner across trusted users
Automation			Higher levels of automation support	For certain phases of flight, the system is fully automated and able to handle both nominal and non-nominal situations
Dynamic airspace			Virtualisation and dynamic airspace configuration	Capacity adjustments are implemented in real time and ensure an optimal and cost-efficient use of resources at any moment across the network (airspace, data, infrastructure and human–machine teaming)
Human roles			Human-centric	Human–machine teaming

New service delivery model and supporting regulatory framework

Mitigation of CO_2 impact	**– 1.6 %**	**– 7.7 %**
Mitigation of total impact (including non-CO_2)	**No**	**Yes**
Integration of zero-emission aircraft	**Limited**	**Yes, full (all types)**
Minimum share of supply of sustainable aviation fuel (SAF)	**Increasing to 20 % by 2035**	**Increasing to 42 % by 2045 and to 70 % by 2050**

FIGURE 10: CRITICAL PATH FOR ROLL OUT BY 2045

Focusing on this critical path will be key to eliminating environmental inefficiencies through enhanced capacity, flight efficiency and predictability, allowing airspace users to fly optimal routes. Interdependencies between performance areas show that inadequate capacity leads to non-optimal aircraft routing and increased environmental impact.

The transition to TBO will result in a progressive reduction of CO_2 emissions. This will be achieved through a more precise and systematic optimisation of each flight's CO_2 footprint, provided by advanced automation and greater air–ground connectivity. Figure 10 illustrates what the transformational changes will mean in real terms, namely a reduction in CO_2 emissions by a further 1 % by phase C and 7.5 % by phase D.

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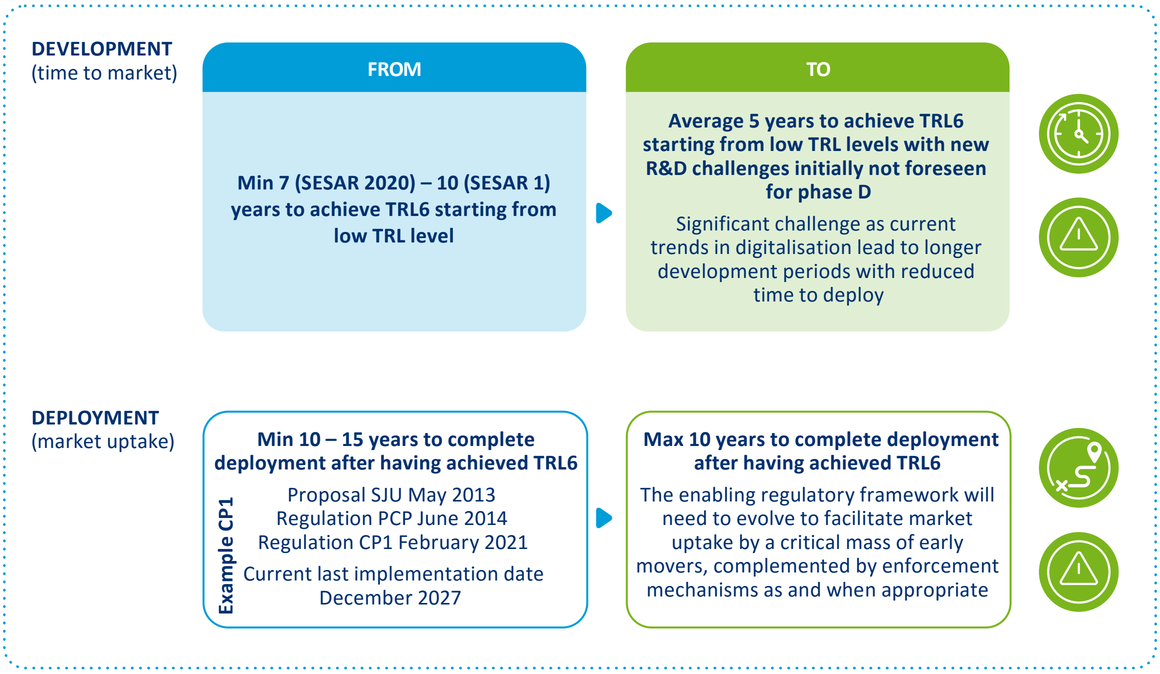
35 Commission Implementing Regulation (EU) 2021/116 of 1 February 2021 on the establishment of the Common Project One supporting the implementation of the European Air Traffic Management Master Plan provided for in Regulation (EC) No 550/2004 of the European Parliament and of the Council, amending Commission Implementing Regulation (EU) No 409/2013 and repealing Commission Implementing Regulation (EU) No 716/2014, OJ L 36, 2.2.2021, p. 10.

Reducing the total impact of ATM on the climate, including non-CO_2 emissions (e.g. the effect of contrails), will be addressed in phase D through coordinated strategies and a revision of environmental performance metrics. This will include the definition of precise eco-sensitive areas with the support of advanced prediction tools. In addition, other solutions will improve local air quality and noise mitigation at airports.

In parallel, phase D will also support the integration of zero-emission aircraft, thereby accommodating the specific needs and flight profiles of a new generation of vehicles, such as battery-electric vehicles for short flights and hydrogen-powered aircraft, which are expected to enter service from 2035 ([36]).

Any delays in the deployment of these elements will delay the overall roll-out of the vision and reduce Europe's ability to deliver the most efficient and environmentally friendly sky to fly in the world.

To achieve this ambition by 2045, the innovation cycle in ATM must be significantly shortened, affecting both the development (time to market) and the deployment (market uptake) of SESAR Solutions, as illustrated in Figure 11. Key milestones include significantly advancing phase D development by 2030, completing phase C deployment by 2035 and, ultimately, completing phase D deployment by 2045.



	FROM	TO
DEVELOPMENT (time to market)	**Min 7 (SESAR 2020) – 10 (SESAR 1) years to achieve TRL6 starting from low TRL level**	**Average 5 years to achieve TRL6 starting from low TRL levels with new R&D challenges initially not foreseen for phase D** Significant challenge as current trends in digitalisation lead to longer development periods with reduced time to deploy
DEPLOYMENT (market uptake)	**Min 10 – 15 years to complete deployment after having achieved TRL6** **Example CP1** Proposal SJU May 2013 Regulation PCP June 2014 Regulation CP1 February 2021 Current last implementation date December 2027	**Max 10 years to complete deployment after having achieved TRL6** The enabling regulatory framework will need to evolve to facilitate market uptake by a critical mass of early movers, complemented by enforcement mechanisms as and when appropriate

FIGURE 11: DEVELOPMENT AND DEPLOYMENT CYCLE CHALLENGES

To set this transition in motion from 2025 to 2030, key activities include completing CP1 implementation, mobilising resources and investments for phase C and D priorities, updating the EPAS according to the SDOs, launching a reflection on a future common project, securing air–ground connectivity transitions, and ensuring continued EU funding and private investments for SESAR beyond the EU's current multiannual financial framework (MFF), which ends in 2027.

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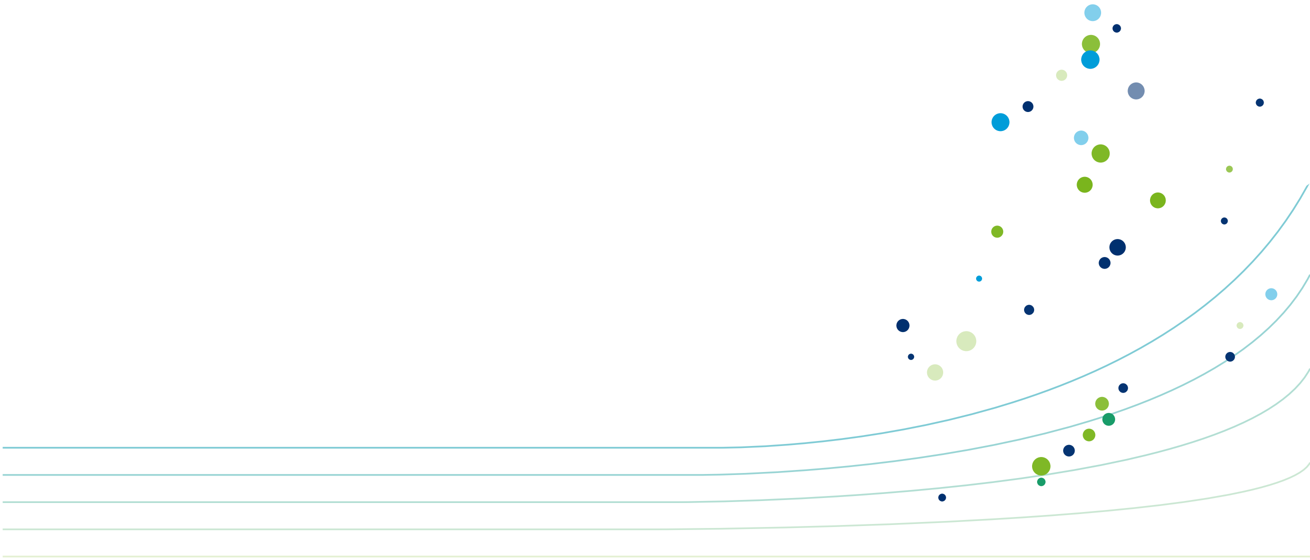
[36] Clean Aviation Joint Undertaking.

4.4 Conditions for successful roll-out

Achieving the key milestones (i.e. in 2030, 2035, 2045) requires the following conditions to be met:

- **Economic regulatory framework.** SES instruments work hand in hand from reference period 4 of the SES performance and charging scheme (37) onwards to promote investments in SDOs (see Chapter 5).
- **EASA regulatory framework and supporting standardisation activities.** Timelines in the EPAS published by EASA, supporting activities (in particular in relation to standardisation) and the Master Plan are fully aligned.
- **Continued support for early movers.** Digital European Sky Demonstrators (38) are expanded to cover the full scope of strategic deployment objectives, becoming also the 'regulatory sandboxes' for the Digital European Sky. EU funds (from the Connecting Europe Facility, Innovation Fund and their successors under the EU's next MFF) are available for supporting deployment objectives under the next MFF from 2028.
- **Future Common Projects.** These will regulate the deployment of those SDOs that require a synchronised and harmonised roll-out at European level.
- **Research resources focused on development priorities.** All research resources are mobilised to deliver on strategic development priorities by 2030; the aviation community embraces this approach to develop next generation platforms. EU (research) funds are available to support further SESAR research under the next MFF from 2028.
- **Involvement of the ATM workforce secured.** Professional staff organisations support development and deployment activities, offer training and foster engagement to gain social acceptance of the changes envisaged by the Digital European Sky.
- **Monitoring of progress.** To maintain the momentum generated by this edition of the Master Plan, the relevant EU bodies work together, and the SESAR 3 JU reports annually to the SESAR 3 JU Governing Board on progress made in relation to deployment and development, taking into account civil–military coordination needs.



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37 European Commission, RP4 refers to the fourth reference period of performance and charging scheme, SES performance and charging.
38 SESAR 3 JU, SESAR Innovation Pipeline.

5. Deployment priorities

This chapter focuses on deployment priorities for Europe, introducing the strategic deployment objectives (SDOs). SDOs are prioritised actions (also referred to as essential operational changes ([39])) that need to be rolled out between 2025 and 2035. These actions are critical for achieving the vision and performance ambitions, and are based on SESAR Solutions either already delivered (having reached technology readiness level (TRL) 6 ([40])) or in the pipeline (expected to reach TRL 6 before the end of 2026).

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[39] 'Essential operational change' means an air traffic management (ATM) operational change that provides significant network performance improvements to the operational stakeholders, as referred to in the ATM Master Plan' (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); see Section A.9.1.

[40] In the Digital European Sky programme, the TRLs are as follows: exploratory research (TRLs 0–2), industrial research and validation (TRLs 3–6), fast-track innovation and uptake (TRLs 2–7) and Digital Sky Demonstrators (TRLs 7 and 8). SESAR Solutions reaching TRL 6 have undergone industrial research, have been validated and are ready for deployment (first industrialisation, followed by implementation).

The SDOs were selected following a prioritisation process that evaluated the relevance and readiness of the supporting SESAR Solutions. The selection was then based on four criteria: the critical role they can play in addressing climate-neutral aviation, capacity and scalability, safety criticality and the uptake of innovative air mobility.

For ATM stakeholders wishing to make local investment decisions on other SESAR Solutions delivered, the full list is available at www.sesarju.eu/catalogue.

As a result, the 10 SDOs presented in Figure 12 provide the basis to trigger accelerated market uptake of SESAR Solutions by a critical mass of early movers and to support the updating of the regulatory framework ([41]). They look beyond the ATM functionalities (AF) already covered by CP1 ([42]). Completing the implementation of CP1 is essential to secure the transition to trajectory-based operations (TBO) covered by SDO 5.

FIGURE 12: STRATEGIC DEPLOYMENT OBJECTIVES LOOKING BEYOND CP1

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[41] EASA, European Plan for Aviation Safety (EPAS) 2023–2025.

[42] Commission Implementing Regulation (EU) 2021/116 of 1 February 2021 on the establishment of the Common Project One supporting the implementation of the European Air Traffic Management Master Plan provided for in Regulation (EC) No 550/2004 of the European Parliament and of the Council, amending Commission Implementing Regulation (EU) No 409/2013 and repealing Commission Implementing Regulation (EU) No 716/2014, OJ L 36, 2.2.2021, p. 10.

In the following sections, each SDO is defined, along with the corresponding required deployment actions (the 'what'), the targeted stakeholders (the 'who' ([43])) and the operating environments (the 'where').

ATM modernisation is a global effort and requires continued cooperation with ICAO and other regions of the world. Section A.8 maps the alignment of the Master Plan with the global air navigation plan (GANP) and flags those activities with a global interoperability dimension that may require ICAO adaptations. Further details on roadmaps are given in the Appendix (Sections A.1–A.6). Details on the content of each SDO (e.g. supporting SESAR Solutions, reference period for starting investment and links to essential operational changes in the previous edition of the Master Plan) are published on the SESAR 3 JU website.

5.1 SDO 1 – Alerts for reduction of collision risks on taxiways and runways

This SDO aims to prevent collisions on the airport surface under increasing traffic in all weather conditions (Table 1). It also aims to mitigate the safety issue assessed according to EASA with an elevated priority category 'undetected occupied runway (SI-2006)' – to prevent runway incursion by aircraft ([44]).

What		Who	Where
ID	**Deployment action**		
1.1	Adapt airport ground safety nets to extend conflicting ATC clearances (CATC) to the entire aerodrome movement area, to enlarge the set of conformance monitoring (CMAC) alerting functions and to provide integrated occupancy/conflict status of a runway.	ANSP	Airport

TABLE 1: SDO 1 – ALERTS FOR REDUCTION OF COLLISION RISKS ON TAXIWAYS AND RUNWAYS

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[43] ANSPs, airspace users, airport operators, the NM, U-space service providers, common information service providers, drone/UAS operators, vertiport operators, the military.

[44] EASA, European Plan for Aviation Safety (EPAS) 2024, 13th edition.

5.2 SDO 2 – Optimising airport and TMA environmental footprint

This SDO aims to optimise the continuity of capacity delivery at airports and in TMAs, while also meeting military needs and avoiding network-wide delays and reducing the environmental impact of ATM (Table 2). It also aims to mitigate the safety issue assessed by EASA with an elevated priority category 'mass diversions (SI-2032)' (45) due to airspace and/or airport closure, where a large amount of displaced traffic leads to an overload for air traffic control (ATC) and increased workload for the flight crew.

What		Who	Where
ID	**Deployment action**		
2.1	Implement collaborative management of regional airports and their integration with Network Manager (NM) by sharing departure planning information (also shared between NM and airspace users).	ANSP, AU, AU MIL, AO, NM	Airport, TMA, En-route, Network
2.2	Implement solutions to better integrate large/very large airports and the network via an enhanced AOPs-NOP tactical, pre-tactical and strategic planning and AOP to AOP collaborative planning process.	ANSP, AU AO, NM	Airport, Network
2.3	Implement environmental performance management at airports and solutions to reduce the airport impact on emissions (single engine taxiing, engine-off taxiing though use of sustainable taxiing vehicles).	ANSP, AU, AO	Airport
2.4	Implement capabilities to better manage arrival constraints between various extended arrival management (E-AMAN) units in cross-border environments and to better integrate the out-of-area inbound flights.	ANSP, AU	Airport, TMA, En-route, Network
2.5	Implement optimised descent operations using merge to point and advanced approach procedures (46) (i.e. second runway-aiming point (SRAP), increased second glide slope (ISGS), increased glide slope to a second runway aiming point (IGS-to-SRAP)), which aim to reduce the environmental impact (e.g. noise, fuel consumption, CO_2 emissions) on the airport's neighbouring communities.	ANSP, AU, AU MIL, AO	Airport, TMA, En-route
2.6	Implement new capabilities to increase airport runway capacity both on arrivals and departures using wake turbulence separations based on static aircraft characteristics, required surveillance performance (RSP) and runway occupancy time (ROT) characterisation of the leader aircraft.	ANSP, AU, AO	Airport, TMA

TABLE 2: SDO 2 – OPTIMISING AIRPORT AND TMA ENVIRONMENTAL FOOTPRINT

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45 EASA, European Plan for Aviation Safety (EPAS) 2024, 13th edition.

46 These advanced procedures can be implemented at airports with different types of approach means supporting vertical guidance (e.g. ground-based augmentation system (GBAS) landing systems or required navigation performance approach procedures (area navigation (APV-Baro) or localiser performance with vertical guidance, enabled by a satellite-based augmentation system), as per Commission Implementing Regulation (EU) 2018/1048 of 18 July 2018 laying down airspace usage requirements and operating procedures concerning performance-based navigation, OJ L 189, 26.7.2018, p. 3 (performance-based navigation regulation)).

5.3 SDO 3 – Dynamic airspace configuration

SDO 3

This SDO aims to enable the dynamic adaptation of ATS capacity to changes in demand, increasing the flexibility of airspace capacity for civil and military users and maximising the productivity of controller teams (Table 3). It also mitigates the safety issue assessed by EASA with an elevated priority category 'mass diversions' (SI-2032) (47), due to airspace and/or airport closure, where a large volume of displaced traffic leads to an overload for ATC and increased workload for the flight crew.

What		Who	Where
ID	**Deployment action**		
3.1	Implement higher levels of granularity and dynamicity in airspace configurations, adjusted to traffic demand and military needs for airspace reservations, enabling cross-border coordination between all civil and military actors.	ANSP, ANSP MIL, AU, AU MIL, NM	En-route, Network
3.2	Implement mission trajectory and dynamic mobile areas (DMAs) of type 1 and type 2 using the improved operational air traffic flight plan (iOAT FPL) into dynamic airspace configuration processes in the medium- to short-term ATM planning phase to support military airspace requirements.	ANSP, ANSP MIL, AU, AU MIL, NM	En-route, Network

TABLE 3: SDO 3 – DYNAMIC AIRSPACE CONFIGURATION

5.4 SDO 4 – Increased automation support

SDO 4

This SDO aims to pave the way for TBOs by allowing controllers to focus on complex tasks rather than on routine activities (Table 4).

What		Who	Where
ID	**Deployment action**		
4.1	Implement sector team configurations, which in specific airspace configurations include the combination of one planning ATCO with two tactical/executive ATCOs in an en-route/eTMA environment.	ANSP	En-route
4.2	Implement automatic speech recognition (ASR), user profile management system (UPMS) and attention guidance (AG) to provide a higher automation environment to support the ATCO role.	ANSP	TMA, En-route

TABLE 4: SDO 4 – INCREASED AUTOMATION SUPPORT

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47 EASA, European Plan for Aviation Safety (EPAS) 2024, 13th edition.

5.5 SDO 5 – Transformation to trajectory-based operations (TBO)

This SDO aims to deliver a fully collaborative environment in which all flight trajectory data are shared, maintained and used by all the concerned actors during all phases of flight (Table 5). Advanced automation tools assist in detecting, analysing and resolving potential conflicts, and in monitoring adherence to agreed and optimised trajectories, while securing a safe, cost-efficient and environmentally optimised trajectory for the whole flight.

What		Who	Where
ID	**Deployment action**		
5.1	Implement enhanced conflict detection and resolution (CD&R) support tools by using aircraft-derived data (i.e. extended projected profile (EPP)) supported by the full implementation of ATS-B2 and high-resolution wind models.	ANSP, AU	TMA, En-route
5.2	Implement multi-element clearances using controller pilot data link communications (CPDLC) with lateral and vertical data link clearances and increased ground automation tools (e.g. CD&R tools) and trajectory prediction supporting the earlier detection and resolution of potential conflicts.	ANSP, ANSP MIL, AU, AU MIL	TMA, En-route
5.3	Implement a dynamic route availability document (RAD) to allow the dynamic management of restrictions based on traffic evolutions, better integration of letters of agreement (LoAs) between ATC centres and NM, and the provision of preliminary flight plans by airspace users. This will feed dynamic network constraints publications initiated the day before operations, to optimise the environmental performance of the network.	ANSP, AU, NM	TMA, En-route, Network
5.4	Implement airspace user capabilities to provide, through the user-driven prioritisation process (UDPP), their preferences and priorities and influence ATFM arrival regulations.	AO, AU, NM	Airport, Network
5.5	Implement interaction tools supporting the full integration of the flight operations centre (FOC) into the ATM network process, and the flight delay criticality concept, to better integrate airspace user priorities in flow management decisions.	ANSP, AU, NM	TMA, En-route, Network
5.6	Exploit new FF-ICE/R1 trajectory services beyond the CP1 services (which are just the filing and trial services) to improve the completeness and accuracy of traffic load calculation and advanced network performance capabilities.	ANSP, ANSP MIL, AU, AU MIL, AO, NM	Airport, TMA, En-route, Network
5.7	Implement seamless ATC–ATC coordination and sharing with NM of the ATC–ATC exchanges (48), encompassing more complex coordination dialogues implying negotiation between controllers across ACC boundaries.	ANSP, ANSP MIL, NM	TMA, En-route, Network

TABLE 5: SDO 5 – TRANSFORMATION TO TRAJECTORY-BASED OPERATIONS (TBO)

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48 Note that the SESAR Deployment Manager's action to build consensus on ATC–ATC TBO interoperability is ongoing.

5.6 SDO 6 – Virtualisation of operations

This SDO aims to make more efficient and flexible use of resources, without being constrained by the geographical, and ultimately organisational, location of the air traffic service unit (Table 6). It also aims to mitigate the safety issue assessed by EASA with an elevated priority category 'mass diversions (SI-2032)' ([49]), due to airspace and/or airport closure, where a large volume of displaced traffic leads to an overload for ATC and increased workload for the flight crew.

What		Who	Where
ID	**Deployment action**		
6.1	Implement virtual centres to enable decoupling of the ATM data service provider (ADSP) and ATSU through service interfaces that support new ways of dynamic ATS delegation (e.g. contingency delegation, night delegation (scheduled), fixed time delegation (scheduled), or 'on-demand').	ANSP, ANSP MIL	TMA, En-route
6.2	Implement multiple remote tower module (MRTM) flexible and dynamic allocation of different MRTMs accommodated within a remote tower centre (RTC) that allows the ATCO to maintain situational awareness for two or more small airports. It includes the implementation of a low-cost surveillance service for supporting remote tower operations.	ANSP, ANSP MIL, AO, AO MIL	Airport

TABLE 6: SDO 6 – VIRTUALISATION OF OPERATIONS

5.7 SDO 7 – Transition towards high performance of air–ground connectivity (multilink)

This SDO aims to improve air–ground data link performance, accelerate technology adoption and achieve economies of scale while reducing the fragmentation that characterises current data link implementation (Table 7).

What		Who	Where
ID	**Deployment action**		
7.1	Implement future air–ground communications network infrastructure, which supports multilink capability and complete mobility between different data links.	ANSP, ANSP MIL, AU, AU MIL	Airport, TMA, En-route, Network
7.2	Implement SatCom class B, which enables data and voice communication services using existing satellite technology systems in oceanic, remote, polar and progressively continental airspace.	ANSP, AU, ANSP MIL	TMA, En-route
7.3	Implement VDL-M2 successor (e.g. terrestrial data link system L-band-digital aeronautical communication system (LDACS), data link for ATM and AOC operations over commercial communication systems (hyper-connected ATM), and satellite communications for both continental and remote/oceanic regions.	ANSP, AO, AU, AU MIL	Airport, TMA, En-route, Network

TABLE 7: SDO 7 – TRANSITION TOWARDS HIGH PERFORMANCE OF AIR–GROUND CONNECTIVITY (MULTILINK)

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[49] EASA, European Plan for Aviation Safety (EPAS) 2024, 13th edition.

5.8 SDO 8 – Service-oriented delivery model (data-driven and cloud-based)

This SDO aims to implement the new service-oriented delivery model (as defined in Section 3.4), making it possible to decouple service provision from local infrastructure (Table 8).

What		**Who**	**Where**
ID	**Deployment action**		
8.1	Implement the new service-oriented delivery model (data-driven and cloud-based) covering all phases of flight and enabling: • open ATM patterns enabling integration of components provided by various system providers to facilitate multi-vendor solutions using open platforms and interfaces; • decoupling of service and infrastructure layers through cloud computing (including the various system components); • a cloud-native architecture of components with standardised and open interfaces that can be deployed on commodity cloud technologies.	ANSP, NM, ANSP MIL	Airport, TMA, En-route, Network

TABLE 8: SDO 8 – SERVICE-ORIENTED DELIVERY MODEL (DATA-DRIVEN AND CLOUD-WBASED)

5.9 SDO 9 – CNS optimisation, modernisation and resilience

This SDO aims to optimise, modernise and increase the resilience and interoperability of CNS infrastructure in Europe (Table 9), building on top of ongoing deployment activities, in particular the ones already included in Commission implementing regulations (PBN, ADS-B, datalink) (50).

What		**Who**	**Where**
ID	**Deployment action**		
9.1	Implement a secured surveillance functionality that enables detection and, when possible, mitigation of security threats that could affect the surveillance chain.	ANSP, ANSP MIL	Airport, TMA, En-route
9.2	Implement minimum operational network (MON).	ANSP, ANSP MIL, NM	TMA, En-route, Network
9.3	Rationalise instrument landing systems (ILS) and implement efficiency measures/methods for more cost-effective maintenance of ILS, providing a link between ICAO Doc. 8071 and national CNS provision.	ANSP, NM, ANSP MIL	TMA, Network
9.4	Optimise surveillance, leveraging terrestrial and space-based information.	ANSP, NM	Airport, TMA, En-route, Network

TABLE 9: SDO 9 – CNS OPTIMISATION, MODERNISATION AND RESILIENCE

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[50] Commission Implementing Regulations 2018/1048 for PBN (including SBAS, RNP/RNAV and LPV), 2020/587 for ADS-B and 29/2009 for datalink.

5.10 SDO 10 – Enable innovative air mobility (IAM) and drone operations

This SDO addresses the safe, secure and sustainable air mobility of passengers and cargo enabled by new-generation technologies integrated in a multimodal transportation system (Table 10). It also helps to mitigate a safety issue assessed by EASA with an elevated priority category 'airborne conflict with an uncrewed aircraft system (SI-2014)' (51).

What		Who	Where
ID	**Deployment action**		
10.1	Implement system support and procedures to integrate instrument flight rules (IFR) RPAS and IAM in airspaces A to C, which are required to have detect and avoid (DAA) systems that perform at least as well as TCAS II (traffic alert and collision avoidance system) and see and avoid.	ANSP, ANSP MIL, AU, AU MIL, Drone/ UAS Operator MIL	TMA, En-route
10.2	Implement foundational (U1) and initial (U2) U-space services as established by the regulatory framework for U-space (Commission Implementing Regulation (EU) 2021/664).	USSP, CISP, Drone/UAS Operator	Very low-level airspace
10.3	Implement a common ATM–U-space interface and dynamic airspace reconfiguration service to help ATC actors in charge of airspace reconfigurations to increase safety, keeping crewed and uncrewed aircraft segregated within the designated U-space airspace.	ANSP, ANSP MIL, AU, AU MIL, AO, AO MIL, USSP CISP, Drone/ UAS Operator	Airport, Vertiport, TMA, En-route
10.4	Implement simultaneous non-interfering (SNI) operations (e.g. parallel or convergent point-in-space (PinS) procedures) and capabilities (i.e. GNSS and the RNP navigation specification) allowing airspace users (e.g. rotorcraft, VTOL-capable aircraft, etc.) to operate to and from airports, vertiports and TMAs without conflicting with other traffic or requiring runway slots.	ANSP, AU, AO, Vertiport Operator, Drone/ UAS Operator	Airport, Vertiport, TMA

TABLE 10: SDO 10 – ENABLE INNOVATIVE AIR MOBILITY (IAM) AND DRONE OPERATIONS

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51 EASA, European Plan for Aviation Safety (EPAS) 2024, 13th edition.

6. Development priorities

This chapter presents strategic development priorities (DPs), which cover the prioritised actions needed to develop future ATM functionalities and roll-out phase D of the Digital European Sky vision. They consider the human dimension of the transformative changes ahead and SESAR's strategic research and innovation agenda (SRIA) ([52]).

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[52] SESAR 3 JU, Strategic Research and Innovation Agenda.

The priorities address new development challenges and expectations for phase D that were not previously envisaged, such as, but not limited to:

- the vision to make Europe the most efficient and environmentally friendly sky to fly in the world;
- the integration of innovative air mobility (IAM);
- higher airspace operations;
- integration of the next generation aircraft for zero-/low-emission aviation by 2035;
- a new security and defence context for ATM in Europe.

The priorities are categorised in accordance with the SESAR Innovation Pipeline ([53]), the process used to transform promising ideas and concepts into tangible solutions for industrialisation and accelerate their market uptake. These include exploratory research, covering fundamental research (FR TRL 0–1) and applied research (AR TRL 1–2), and industrial research (IR) (TRL 2–6), including fast-track (up to TRL 7). Each DP details specific actions to be taken and links these with the relevant flagship ([54]) in the current SESAR Digital European Sky programme.

Table 11 lists the 12 priorities for future development activities in ATM from 2025.

DP	Strategic development priorities	
IR-1	Transformation to trajectory-based operations	Industrial research
IR-2	Transition towards high performance of air–ground connectivity (multilink)	
IR-3	Future en-route and TMA ground platforms	
IR-4	Future airport platform	
IR-5	Autonomy and digital assistants for the flight deck	
IR-6	U3 U-space advanced services, IAM and vertiports	
AR-1	Research to help shape the future regulatory framework for a Digital European Sky	Exploratory research
AR-2	Definition of U4 U-space full services	
AR-3	Integration of the next generation aircraft for zero-/low-emission aviation	
FR-1	ATM impact on climate change	
FR-2	Digital flight rules	
FR-3	Investigate quantum sensing and computing applied to ATM	

TABLE 11: STRATEGIC DEVELOPMENT PRIORITIES (DPs) ([55])

In the following sections, each DP is defined with the corresponding required development actions (the 'what').

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53 SESAR 3 JU, SESAR Innovation Pipeline.
54 SESAR 3 JU, SESAR 3 JU Flagships; see Section A.9.2.
55 AR, applied research; FR, fundamental research.

6.1 Industrial research priorities

These six DPs and supporting development actions in Table 12 define the priorities for industrial research (IR TRL 2–6), including fast-track (up to TRL 7), from 2025.

Development priority	Description	Development action
IR-1: Transformation to trajectory-based operations	This development priority focuses on completing the industrial research needs that are identified in the TBO roadmap.	**IR-1-01:** Integrated air–ground trajectory management based on ATS-B2, including the extension for lower airspace and airport surface. **IR-1-02:** Development of FF-ICE, including FF-ICE pre-departure enhancement and FF-ICE/R2. **IR-1-03:** Advanced network trajectory synchronisation in the execution phase. **IR-1-04:** Connected and integrated flight management system (FMS), electronic flight bag (EFB) and flight operations centre (FOC) functionalities for trajectory optimisation. **IR-1-05:** Dynamic route availability document (RAD) towards a RAD by exception environment.
IR-2: Transition towards high performance of air–ground connectivity (multilink)	Covers the integration of non-safety, commercial links into a hybrid communication infrastructure for ATM safety communication needs, the complete development of the new terrestrial link LDACS, and innovative ways to support intelligent data pre-processing and integration, both on ground and onboard the aircraft for air–ground exchange of data (e.g. meteorological data).	**IR-2-01:** Complete development of successor(s) to VHF data link mode 2 (VDL-M2): L-band digital aeronautical communications system (LDACS), hyper-connected ATM, and satellite communications (SatCom class A) covering civil–military dual use. **IR-2-02:** Aircraft as a sensor, including transmission of humidity information to ground.

Development priority	Description	Development action
IR-3: Future en-route and TMA ground platforms	Targets the transformation of both cruise and climb/descent flight phases into highly automated environments enabled by full air–ground integration. The aim is to implement a service-oriented, cloud-based model that allows dynamic capacity adjustment to meet airspace user demands. Focus areas include enhancing cyber-resilience, leveraging artificial intelligence for flight path optimisation and promoting civil–military collaboration for seamless airspace management.	**IR-3-01:** Addresses the next generation ATC platform, fully leveraging aircraft capabilities. This includes supporting a data-sharing service delivery model, resilient integrated CNS/MET as a service and traffic synchronisation, accommodating the specific needs of the military, innovative air mobility (IAM), higher airspace operations (HAO) and U-space. **IR-3-02:** AI capabilities enabling the next generation platforms. **IR-3-03:** Cyber-resilience and cyber-security capabilities enabling the next generation platforms. **IR-3-04:** Separation management for high levels of automation. **IR-3-05:** Demand capacity balancing (DCB) and airspace configuration concepts for high levels of automation. **IR-3-06:** Future human–machine teaming. **IR-3-07:** Ground capabilities for reducing the ATM environmental footprint. This includes climate-optimised trajectories covering non-CO_2 effects (e.g. contrails), environmentally optimised climb and descent operations, advanced required navigation performance green approaches, dynamic allocation of arrival and departure routes considering noise and local air quality, green ATC capacity concept, flexible eco-friendly clearances, wake energy retrieval (WER), integration of sustainable aviation fuels (SAF) and zero emissions aircraft and environmental performance dashboards. **IR-3-08:** Geometric altimetry. **IR-3-09:** CNS capabilities to increase ATM system robustness (e.g. satellite-based multilateration (MLAT), GBAS dual frequency/multi-constellation leveraging Galileo and providing robust protection against jamming and spoofing).

Development priority	Description	Development action
IR-4: Future airport platform	Targets the evolution of airside operations, including aircraft turnaround, taxi, and take-off and landing clearances, into a highly automated environment. The aim is to develop a future platform incorporating advanced technologies and a service-oriented, cloud-based model. This model allows dynamic capacity adjustment to meet the demands of all airspace users while improving safety and environmental sustainability. Key areas of focus include enhancing cyber-resilience, leveraging artificial intelligence and fostering civil–military collaboration for airport operations management.	**IR-4-01:** Addresses the next generation airport platform, fully leveraging aircraft capabilities. This includes supporting the data-sharing service delivery model, interconnected with other airports and their third parties (e.g. ground handlers), ANSPs, NM and CNS/MET as a service, facilitating the accommodation of IAM, the interface with U-space, as well as specific needs from the military. **IR-4-02:** AI capabilities enabling the next generation of airport platforms. **IR-4-03:** Cyber-resilience and cyber-security capabilities enabling the next generation of airport platforms. **IR-4-04:** Airport solutions for reducing environmental impact of operations. This includes green taxiing-related concept and environmental performance dashboards. **IR-4-05:** Future human–machine teaming. **IR-4-06:** Optimisation of runway throughput. **IR-4-07:** Smart airports, airports as multimodal nodes and the passenger experience.

Development priority	Description	Development action
IR-5: Autonomy and digital assistants for the flight deck	Focuses on increasing airborne automation and autonomy, and the collaboration between air and ground for the integration of all airspace users. Development of onboard capabilities and advanced digital technologies (e.g. digital assistance to the flight crew) to support the flight crew during complex scenarios, reducing workload while improving safety and efficiency. The transition to single pilot operations (SiPO) is being explored, balancing societal expectations for human cockpit presence with increased automation for automatic flight phases.	**IR-5-01:** Single pilot operations (SiPO). This includes new sensors and aircraft architectures for the evolution towards SiPO/highly automated operations. **IR-5-02:** Increased automation assistance for the pilot for ATM tasks. This includes improved flight-deck HMI and procedures for CPDLC and voice-less technology. **IR-5-03:** Highly automated ATM for all airspace users. This includes performance-based CNS enablers (assured navigation for robust ATM/CNS environment for all phases of flight, alternative positioning, navigation and timing (A-PNT) providing enhanced robustness against jamming and spoofing, leveraging Galileo, electronic conspicuity, sense and avoid, and enhanced distance measuring equipment (eDME)) to facilitate the integration of advanced airborne automation and future ATC platforms, as well as accommodating IAM and interfacing with U-space. **IR-5-04:** Airborne capabilities for reducing ATM's environmental footprint. This includes wake energy retrieval (WER), energy-based operations and environment-driven trajectory optimisation.

Development priority	Description	Development action
IR-6: U3 U-space advanced services, IAM and vertiports	Focuses on enabling IAM operations with VTOL-capable aircraft (VCA) and UAS in complex environments and congested areas, including vertiport integration as an inherent component of an efficient and sustainable multimodal transportation system. This will be supported by the development of U3 U-space advanced services, which build on U1 and U2 U-space services under implementation (following Commission Implementing Regulation (EU) 2021/664), IAM integration into all types of airspace and vertiports under both instrument meteorological conditions (IMC) and visual meteorological conditions (VMC).	**IR-6-01:** U3 U-space advanced services addressing aspects such as common altitude reference, collaborative interface with ATC, tactical conflict detection and resolution and fairness in strategic deconfliction. **IR-6-02:** CNS capabilities for U-space, which includes detect and avoid and collision avoidance for UAS, and the use of mobile networks by U-space (including performance-based communication and surveillance services using a mobile network infrastructure). **IR-6-03:** Extending the U-space ecosystem. This includes the use of U-space services by commercial aircraft, general aviation, crewed VCA, and the use of U-space services outside U-space airspace. **IR-6-04:** Enabling IAM/VCA (crewed and uncrewed) operations, including in complex environments, congested areas and vertiports. This includes IAM operational procedures enabling access to all types of airspace and vertiports (both VMC and IMC) and IAM automation, including simplified vehicle operations, automatic take-off and landing (TOL), resilient navigation and energy management.

TABLE 12: INDUSTRIAL RESEARCH PRIORITIES

6.2 Exploratory research priorities

The six DPs in Table 13 define the priorities from 2025 for exploratory research (TRL 0–2), split between applied research (AR) and fundamental research (FR). Unlike for industrial research, they do not contain specific development actions, as these activities address the exploration of science and knowledge that will help to define future development activities in ATM.

Development priority	Description
AR-1: Research to help shape the future regulatory framework for a Digital European Sky	Focuses on supporting the evolution of the future regulatory framework to facilitate the implementation of the ATM Master Plan as well as the supporting actions identified in the EPAS. For example, methods to evaluate the performance of ATM/ANS ground equipment and determine appropriate assurance levels, the application of airspace classification in Single European Sky airspace, the impact of automation on the air traffic controller role (evolution of the ATCO role from executor to supervisor), AI assurance, human factors and safety risk mitigation.
AR-2: Definition of U4 U-space full services	Aims to explore the range of U-space services beyond U3, enabling the full potential of innovative air mobility (IAM) at scale.
AR-3: Integration of the next generation aircraft for zero-/low-emission aviation	Explores the ATM aspects of the integration of next-generation aircraft for zero-/low-emission aviation, as foreseen in the AZEA CONOPS (56) and the Clean Aviation JU programme (57).
FR-1: ATM impact on climate change	Aviation contributes significantly to greenhouse gas emissions and other pollutants that impact climate change. Understanding the exact magnitude of this impact, as well as the mechanisms involved, is essential for developing effective ATM optimisation strategies that consider the total climate impact of each flight and that can be automated. Accurate scientific data are necessary to develop evidence-based optimisation algorithms and rules aimed at reducing the environmental impact of aviation. Without comprehensive research, it’s challenging to implement measures that effectively balance, for example, the CO_2 vs non-CO_2 impacts.

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56 Alliance for Zero-Emission Aviation.
57 Clean Aviation JU.

Development priority	Description
FR-2: Digital flight rules	Focuses on the exploration and implementation of digital flight rules, a proposed new set of rules for an ATM system that would operate with significantly higher levels of automation for ground systems as well as autonomy for airborne systems. Indeed, higher levels of automation, autonomy and new data services may prompt the need for adjustments to rules such as PANS-OPS to ensure that new technologies support an increase in safety, compatibility, operational efficiency and international harmonisation.
FR-3: Investigate quantum sensing and computing applied to ATM	Focuses on exploring the potential applications of quantum sensing and computing within ATM (e.g. cybersecurity, queue management). Quantum computing is a rapidly emerging technology and promises to revolutionise the computing landscape with its potential for high-speed and high-capacity data processing. In the context of ATM, quantum computing could significantly enhance the service-oriented architecture, improving efficiency and accuracy in air traffic control and management. This priority aims to position ATM to leverage advancements in quantum technology, ensuring that the sector stays at the forefront of technological innovation. It will involve studying the potential benefits and challenges of integrating quantum sensing and computing into ATM and developing strategies to implement this technology effectively.

TABLE 13: EXPLORATORY RESEARCH PRIORITIES

7. Benefits, investment needs and risks

This chapter outlines the expected impacts in terms of benefits and investment needs of the planned roll-out of the vision by 2045. The chapter also identifies key risks and proposes corresponding mitigation actions.

7.1 Expected benefits and impact

Achieving the performance ambitions set out in the vision (Section 3.2) is essential for the aviation sector, as they represent one of the few viable short- to medium-term technological pathways towards net-zero European aviation, as identified by the Destination 2050 report (58). Beyond climate protection, these advancements promise substantial direct benefits for all stakeholders in the aviation value chain. Importantly, they also serve citizens by enabling aviation to connect people and transport goods, while supporting a wide range of applications beyond transport, such as in defence and security and in the digital economy (e.g. drone-enabled services). They add value by ensuring speed, predictability, reliability and resilience within a global network, over any distance, while minimising the impact on the environment.

This benefit assessment therefore covers 2025–2050 (59), using 2023 performance levels as a baseline, which reflect near pre-COVID-19 traffic levels. To adopt a conservative approach, the actual performance inefficiencies observed in 2023 were considered to represent the maximum benefit pool achievable through the implementation of SESAR, even though it is widely recognised that system performance would deteriorate further without SESAR. The projected increase in benefits over time is consistent with the planned roll-out of CP1 and phases C and D of the Digital European Sky vision.

For CP1, the benefits are well documented (60). The benefits for phase C are calculated based on SESAR validation exercises and are enhanced by a network impact assessment performed by the Network Manager to provide the most accurate future benefit projections. For phase D, which is still in its early development stages, benefits have been assessed from the top down based on expert judgement.

Monetised benefits

Table 14 provides an overview of the performance improvements that can be monetised. The STATFOR long-term traffic forecast (April 2022) (61) is used as a reference, with a base traffic scenario of + 57 % and a high-traffic scenario of + 92 % by 2050 compared with 2023. The ambitions for phase D are set to provide optimal performance, aiming for an en-route air traffic flow management (ATFM) delay of 0.35 minutes per flight and eliminating any fuel inefficiency. These ambitions surpass the current regulatory target of 0.5 minutes of en-route ATFM delay per flight (62). These values consider trade-offs and interdependencies, which limit the possibility of achieving maximum efficiency in all performance areas, as documented by the Performance Review Body and its 2023 performance review report. The ranges provided for airspace and airport capacity indicate potential fluctuations in line with uncertainties in long-term traffic demand and the need to maintain current safety and security levels, especially with the introduction of commercial drone flights. The analysis assumes that there will be no increase in accidents involving ATM/air navigation service contributions and that security incidents causing critical disruptions to service provision will be prevented.

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58 Destination 2050, Destination 2050 – A route to net zero European aviation.

59 The year 2050 was chosen for measuring the benefits of the full deployment of the Digital European Sky programme by 2045, which coincides with the policy goal of decarbonising aviation.

60 Reference for full CP1 benefits is 'Cost–benefit analysis update 2024 (draft), version 1.01'.

61 Eurocontrol, STATFOR interactive dashboard.

62 The targets used in SES performance and charging scheme reference periods 3 and 4 are applicable until 2029.

Performance impact (KPA)	Unit	Reference year (2023)(*)	CP1 (up to 2030)	CP1 + Phase C	Phase D	Expected impact by 2050
Airspace capacity (en-route and TMA)	%	8.5 million flights(*)	+ 34 %	+ 60 %	+ 40 % + 80 %	+ 100 % + 140 %
Airport capacity	%	17.9 million movements(**)	–	+ 15 %	+ 1 % + 5 %	+ 16% + 20 %
Environment (fuel reduction)	kg / flight	6 400	– 22	– 109	– 491	– 600
	%		– 0.3 %	– 1.6 %	– 7.7 %	– 9.3 %
Passenger time saving (departure punctuality)	minute / flight	18	–	– 0.9	– 6.1 – 8.1	– 7 – 9
Cost-efficiency (air navigation services cost reduction)	EUR / flight	1 077	– 26	– 164	– 54	– 209

* There were 10.1 million actual flights, generating an average delay of 1.82 minutes/flight (based on Eurocontrol, Performance Review Report 2023 – An assessment of air traffic management in Europe). The total of 8.5 million flights refers to the number of flights that the network could handle, offering a quality of service of 0.5 minutes of en-route ATFM delay per flight. This estimation is based on the formula used in Eurocontrol's 2001 performance review report to convert traffic into capacity.

** Instrument flight rule movements (arrivals and departures) at ECAC airports in 2023 (based on Eurocontrol, Performance Review Report 2023 – An assessment of air traffic management in Europe).

TABLE 14: EXPECTED PERFORMANCE IMPACT BY 2050 COMPARED WITH 2023

Table 15 shows the direct benefits in euro. Although the benefits associated with phase D are more uncertain than those quantified for CP1 and SDOs, they are expected to be substantial. The primary drivers of these benefits are anticipated to be savings related to the environment and passenger time.

SESAR benefits (EUR billion) by 2050(*)	CP1(**) (up to 2040)	Phase C	Phase D	Total
Airspace capacity (en-route and TMA)	23.5	54	13	**90**
Airport capacity	2	16	2.5	**20**
Environment (fuel and CO_2)	10	14	63	**87**
Passenger time saving (departure punctuality)	Counted in terms of airspace and airport capacity	14	66.5	**81**
Cost-efficiency (air navigation services cost reduction)	6	27.5	6.5	**40**
Total cumulative benefits	**41**	**126**	**151**	**318**

* All figures are rounded except those for CP1.

** Cost–benefit analysis update 2024 (draft), version 1.01.

TABLE 15: SESAR BENEFITS THAT CAN BE MONETISED BY 2050

Benefits for the environment

In 2023, the total CO_2 emissions from aviation in Europe was approximately 150 million tonnes. This figure represents a significant increase from the reduced levels during the COVID-19 pandemic. This increase in emissions highlights the need for the aviation sector to intensify efforts to achieve ambitious environmental targets, including the transition to sustainable aviation fuels (SAF) and the introduction of low-emission aircraft.

In the period up to 2050, SESAR will play a key role in reducing the environmental impact of aviation in Europe, addressing both CO_2 and non-CO_2 emissions. Initiatives such as the transition to SAF and the gradual entry into service from 2035 of low-emission aircraft will complement this effort.

As illustrated in Figure 13, it is estimated that 400 million tonnes of CO_2 could be saved with the roll-out of the vision by 2050, in addition to the savings achieved from the introduction of SAF, as mandated by the relevant EU regulation (63). This amount is close to 3 years' worth of total CO_2 emissions from aviation in the EU.

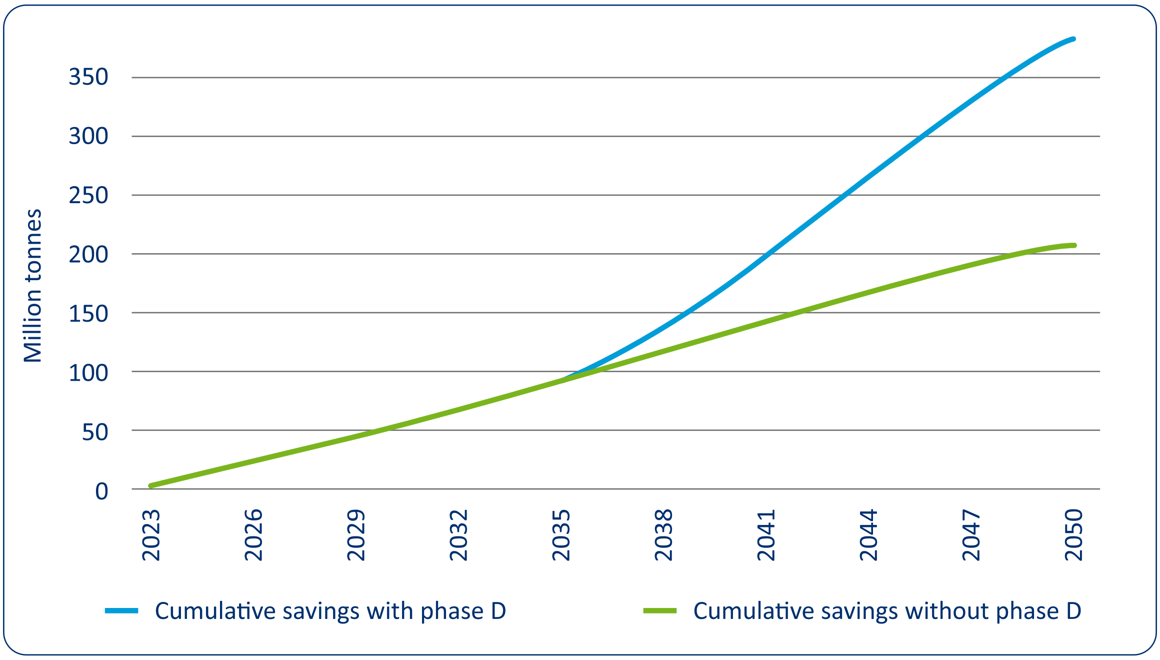

FIGURE 13: CONTRIBUTION TO CO_2 EMISSIONS REDUCTION

7.2 Investment needs

The investments calculated in this section represent the deployment of the vision across the ECAC region, excluding research and operational expenditure. Figure 14 indicates an aggregated investment of EUR 25.5 billion between 2025 and 2050 by all stakeholders (i.e. crewed and uncrewed civil and military, and Network Manager). Minor residual investments are expected between 2046 and 2050, mainly addressing aircraft modifications. In addition, the roll-out of phase C by 2035 includes one-off costs (write-offs) linked to reallocating resources to help secure the timely implementation of the new approach to service delivery (SDO 8) and CNS optimisation (SDO 9), which in the long run will reduce the overall cost of rolling out SESAR.

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63 ReFuelEU aviation.

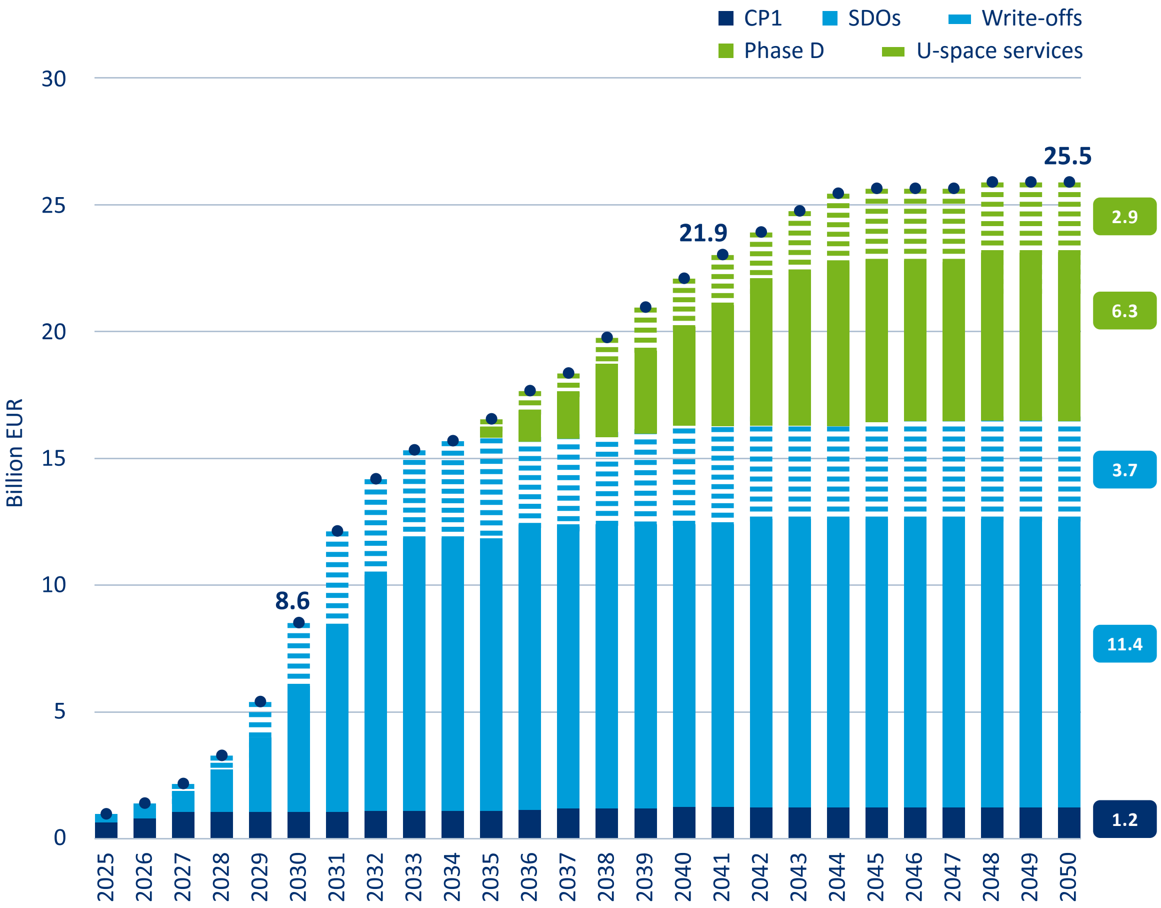

FIGURE 14: CUMULATIVE INVESTMENT NEEDS TO DEPLOY SESAR

Phases A and B (CP 1)

The remaining investment needed to fully deploy CP1 (phases A and B) is estimated at up to EUR 1.2 billion (a quarter of the total investment in CP1). An estimated 90 % of these investments (EUR 1.1 billion) are required to finalise their deployment on the ground by the end of 2027. The remaining 10 % (EUR 100 million) is allocated to airspace user fleet equipage between 2028 and 2045.

Phase C (strategic deployment objectives)

The investment effort needed to deploy SDOs covering phase C is estimated at EUR 11.4 billion between 2025 and 2035. In addition, EUR 3.7 billion is estimated as write-offs to accelerate the transition to the new service delivery model and CNS optimisation.

ANSPs play a pivotal role in accelerating the market uptake of SDO-related solutions. As illustrated in Figure 15, their investments in this phase correspond to investment planning in the context of the SES performance and charging scheme, starting in reference period 4 (RP4) with a total of EUR 4.0 billion investment for SDOs. The bulk of ANSP investments are expected to occur in the next reference period, RP5, requiring an estimated EUR 8.3 billion. Despite the lower level of investment envisaged for other major stakeholders, their contribution will be key to increasing the overall performance benefits. These capital expenditure (CAPEX) volumes are, broadly speaking, in line with historic CAPEX volumes for ANSPs (64); however, SESAR investment needs may put pressure on other CAPEX-intensive investments not related to the Master Plan (e.g. towers, buildings and facilities).

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64 According to the Performance Review Body of the Single European Sky's 2023 annual monitoring report, which covers the SES area (comprising Member States, Norway and Switzerland – not the whole ECAC area, which is the geographical scope of the Master Plan), in reference period 3 of the performance and charging scheme the total EU-wide en-route and terminal CAPEX allocated to air navigation services included in performance plans amounted to EUR 5.2 billion.

Phase D

The investment effort for the deployment of phase D between 2035 and 2045 is estimated at one third of all the cumulative investment needs (i.e. EUR 9.2 billion), in line with the assumptions made in the 2020 edition of the Master Plan. Approximately EUR 2.9 billion will be dedicated to U3 and U4 services; U-space service providers and drone operators are expected to be the major investors.

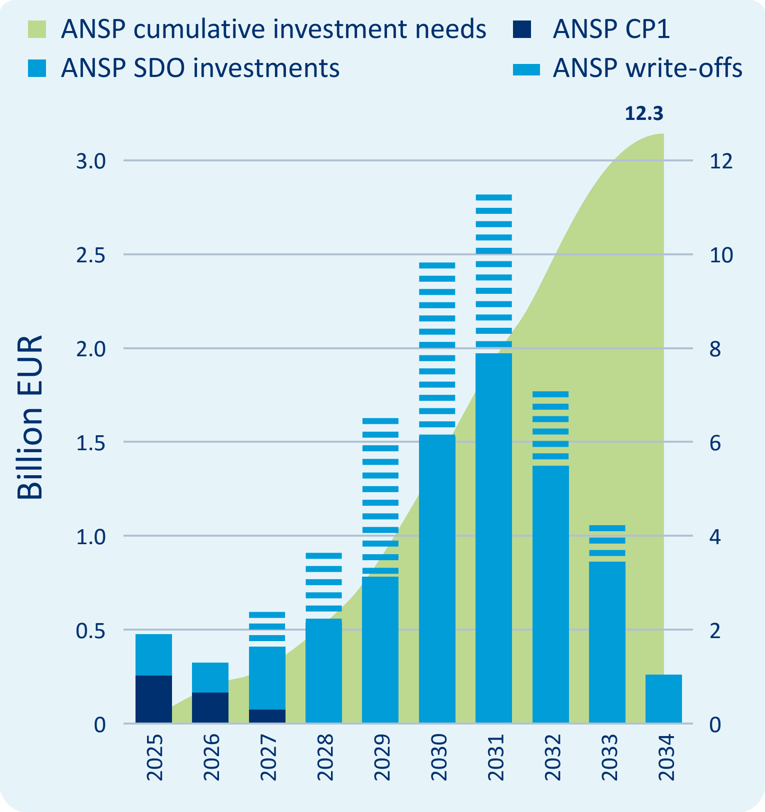

FIGURE 15: ANSP INVESTMENTS

7.3 Return on investment

As illustrated in Figure 16, the potential operational benefits for investors in SESAR solutions significantly outweigh the required investments. By 2050, the combined benefits associated with SESAR deployment across airport and airspace capacity, fuel efficiency, CO_2 emission reduction, passenger time savings and the cost efficiency of air navigation services is estimated at approximately EUR 318 billion.

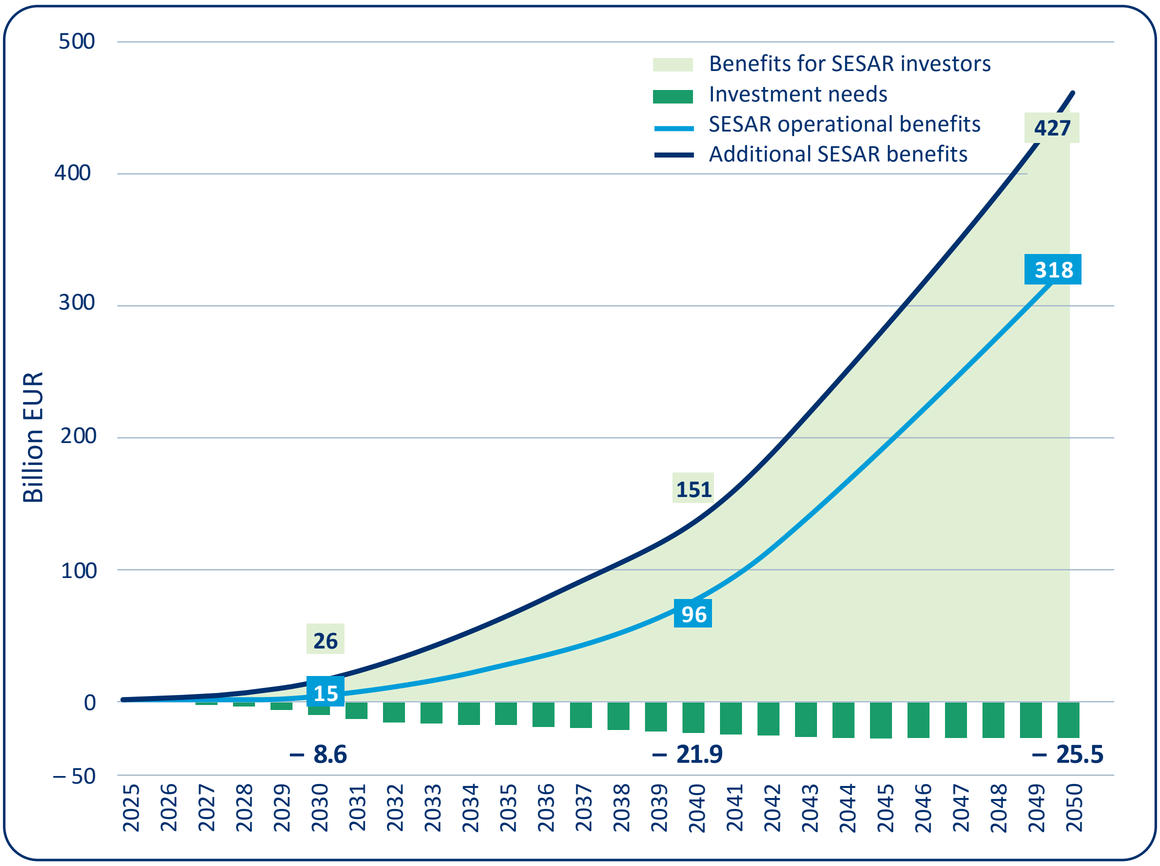

FIGURE 16: CUMULATIVE PERFORMANCE BENEFITS AND INVESTMENTS (65)

Activities directly enabled by SESAR investments (e.g. value of additional flights) will generate additional value, expected to amount to EUR 109 billion (see Figure 16). The projected overall benefits for SESAR investors are estimated at EUR 427 billion by 2050.

The return on investment for investors (66) (excluding U-space) is projected to be EUR 7 for every euro invested in SESAR by 2040, increasing to EUR 17 by 2050 (67).

Direct benefits for the European economy and society (see Figure 17) will be substantial, totalling approximately EUR 1 375 billion. Every euro invested in SESAR is estimated to result in EUR 54 in socio-economic benefits.

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65 The figure takes into account investments in both crewed and uncrewed aviation but excludes benefits for U-space and remotely piloted aircraft systems.

66 Return on investment measures the return (profit or loss) generated on an investment relative to its costs.

67 Further information is available on the SESAR 3 JU website in the European ATM Master Plan 2025 – Benefits and Investment Needs – Companion Document.

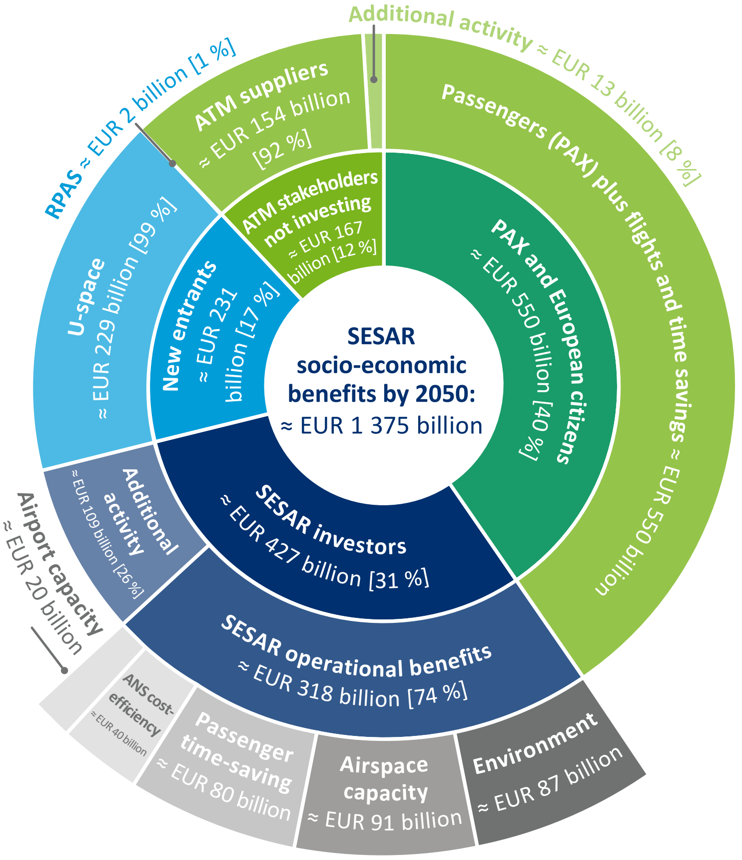

FIGURE 17: SOCIO-ECONOMIC BENEFITS BY 2050 (68)

7.4 Sensitivity analysis

A sensitivity analysis confirms that the benefits of implementing SESAR greatly exceed its costs to all operational actors in ATM, even under scenarios of 0 % growth, significant cost overruns and delays in deployment, or if any of the projected benefits are substantially overestimated (Figure 18).

Sensitivity drivers	Value	Range	Net benefits by 2050 (EUR 293 billion)
Deployment of phase D	2035 – 2045	+/- 5 years	– 36 + 67
Traffic growth	STATFOR base + 57 %	0 % to 92 %	– 18 + 89
Fuel efficiency potential for phase D	491 kg / flight	– 20 % to + 20 %	– 12 + 12
Fuel price	STATFOR base (EUR / kg)	– 50 % to + 50 %	– 25 + 25
Passenger time saving potential for phase D	8.1 min / flight	– 50 % to + 50 %	– 34 + 34
Investment	EUR 25.5 billion	+ 20 % to – 30 %	– 2 + 3

FIGURE 18: SENSITIVITY ANALYSIS FOR PHASE D

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68 ANS, air navigation service; PAX, passenger traffic.

Reductions in fuel efficiency and fuel prices have a relatively minor effect on benefits. By contrast, the benefits are positively influenced by an accelerated deployment of phase D and higher traffic forecasts, particularly compared with a zero-growth scenario after 2040 (i.e. a pessimistic scenario). In this regard, changes in benefits are not symmetric, highlighting a higher positive elasticity. This indicates the need to significantly shorten the innovation cycle in ATM, affecting both the development (time to market) and deployment (market uptake) of SESAR Solutions, as highlighted in Section 4.3.

7.5 Associated risks

The Master Plan addresses the most significant risks associated with the delivery of the vision and the associated performance ambitions (Table 16). The presence of risks does not mean that they will actually materialise; rather, it means that the risks have been identified and are to be adequately managed so that they do not affect the execution of the Master Plan.

Risk	Impact	Mitigation action
Investments in deployment priorities identified in the Master Plan are not supported.	Phase C deployment milestone (by 2035) is not met.	SES instruments work hand in hand (as of reference period 4) to promote investments in SDOs.
Delay in CP1 implementation.	Phase C deployment milestone (by 2035) is not met.	Monitoring of CP1 implementation progress by the SESAR Deployment Manager (SESAR DM).
Delay in delivering the last SESAR solution for phase C.	Phase C deployment milestone (by 2035) is not met.	Monitoring of development progress by SESAR 3 JU.
EASA's regulatory framework is not sufficiently supportive for a critical mass of early movers to deploy the priorities identified in the Master Plan.	Phase C deployment milestone (by 2035) is not met.	The EPAS of EASA and its supporting standardisation framework is fully aligned with timelines of the Master Plan.
There is no incentive for early movers to deploy ahead of everyone else.	Phase C deployment milestone (by 2035) is not met.	Digital Sky Demonstrators are expanded to cover the full scope of strategic deployment priorities, becoming also regulatory sandboxes for the Digital European Sky. EU funds (e.g. the Connecting Europe Facility, Innovation Fund and their successors under the next MFF) should be made available to support the deployment of SDOs under the next MFF, from 2028.

Risk	Impact	Mitigation action
Insufficient level of coordination and harmonisation of SDO deployment.	Phase C deployment milestone (by 2035) is not met.	Future Common Project regulations support the deployment of those SDO elements that require synchronised and harmonised roll-out at the European level. The preparation of the next Common Project starts in 2025 for adoption in 2027, supporting the roll-out of the SDOs by end of 2035. Appropriate coordination (including civil–military), harmonisation and monitoring by the relevant European actors.
Insufficient level of global harmonisation.	Phase C deployment milestone (by 2035) is not met.	ATM functionalities within the scope of SDOs requiring global harmonisation are recognised in the ICAO's GANP as priorities for global harmonisation fostering the necessary adaptation of the global regulatory framework.
Failure to manage human resources properly (e.g. staff and skill shortages, human factors, competency of staff and change management).	Delays in the deployment of phases C and D.	Adequately plan human resources to secure the sufficient availability of staff with the right skills. Involve the ATM workforce through their professional staff organisations in the development and deployment activities, training and engagement to gain social acceptance of the changes envisaged by the vision.
Lack of resources and time to complete the development of phase D by 2030 due to increased ambition in scope for phase D.	Phase D development milestone (by 2030) is not met.	All research resources in the ATM Innovation Pipeline are mobilised to significantly advance development priorities by 2030, and the research and development community embraces the approach to develop next-generation platforms. EU funds (research) should be made available to support further SESAR research under the next MFF from 2028.

TABLE 16: KEY RISKS AND ASSOCIATED MITIGATION MEASURES

Appendix

This appendix provides key roadmaps connecting development and deployment activities (A.1 to A.6), followed by a list of business services for a typical ACC (A.7), a mapping of the Master Plan with the global air navigation plan (GANP) (A.8), a mapping of essential operational changes to flagships (A.9) and a list of abbreviations (A.10).

A.1 TBO roadmap

The roadmap in Figure 19 provides a timeline for the development and deployment activities addressing network, air traffic control and intra-regional trajectory-based operations (TBO), from the 2025 deployment baseline towards the 2045 vision.

The roadmap is grouped into three areas based on the stakeholders involved:

- **Network TBO** are trajectory management processes involving the flight operations centre (FOC) and network manager (NM) supported by the local air traffic flow management (ATFM) units at the air navigation service providers (ANSPs) during the pre-departure and post-departure phases.
- **ATC TBO** are trajectory management processes involving the flight deck and the air traffic control (ATC) units at the ANSPs during the post-departure phase.
- **Regional TBO** are trajectory management processes involving the NM, ANSPs and airports during the pre-departure and post-departure phases. Neither the FOC nor the flight deck are involved in regional TBO concepts.

As illustrated in the roadmap, global harmonisation efforts are required and already under way in ICAO.

While the roadmap describes the envisaged European implementation of TBO, it should be noted that the TBO concepts are globally applicable.

Vision and key milestones for TBO

Phase 1 (by 2030). This phase involves the implementation of Common Project 1 (CP1), including notably a first major step towards TBO, with the integration of the airport operations plan (AOP) and iAOP airports into the network (as defined in CP1-AF2 and AF4), the deployment of the first set of flight and flow information for a collaborative environment (FF-ICE) services (as defined in AF5 of CP1); and initial trajectory information sharing (as defined in AF6 of CP1). Significant progress will also have been made in advancing and completing the development priorities for TBO identified in the Master Plan.

Phase 2 (by 2035). This phase involves the implementation of the strategic deployment objectives (SDOs) covering TBO. It includes conflict detection and resolution tools enhanced with automatic dependent surveillance – contract (ADS-C) data downlinked from the aircraft; the initial set of controller pilot data link communications (CPDLC) v2 clearances in en-route (addressing complex lateral trajectory revision clearances and simple vertical clearances); dynamic route availability document (RAD); increased provision of trajectory updates by ANSPs and airports to the NM; a network trajectory service for airspace users and ANSPs; the incorporation of user priorities for departures and arrivals, including the concept of flight delay criticality; the full deployment of the improved operational air traffic flight plan; full FF-ICE/R1 (beyond CP1 services); and seamless cross-border ATC–ATC coordination.

Phase 3 (by 2045). SESAR development activities covering advanced TBO functionalities will have been rolled out and both the planning and the execution phase of every flight will be optimised. This covers the full development of FF-ICE potential; the development of advanced ATS-B2 automatic dependent surveillance, incorporating more complex clearances and extending to the lower airspace and airport surface, the network-wide standard terminal arrival (STAR) uplink service and flexible eco-efficient clearances; advanced network trajectory synchronisation in the execution phase; connected aircraft with full integration of the flight management system (FMS), electronic flight bag (EFB) and airline operations communications (AOC) functionalities in the ATM system for trajectory optimisation during the execution of the flight; the digitalisation of letters of agreement (LoA); and the dynamic RAD evolution towards a 'RAD by exception' environment.

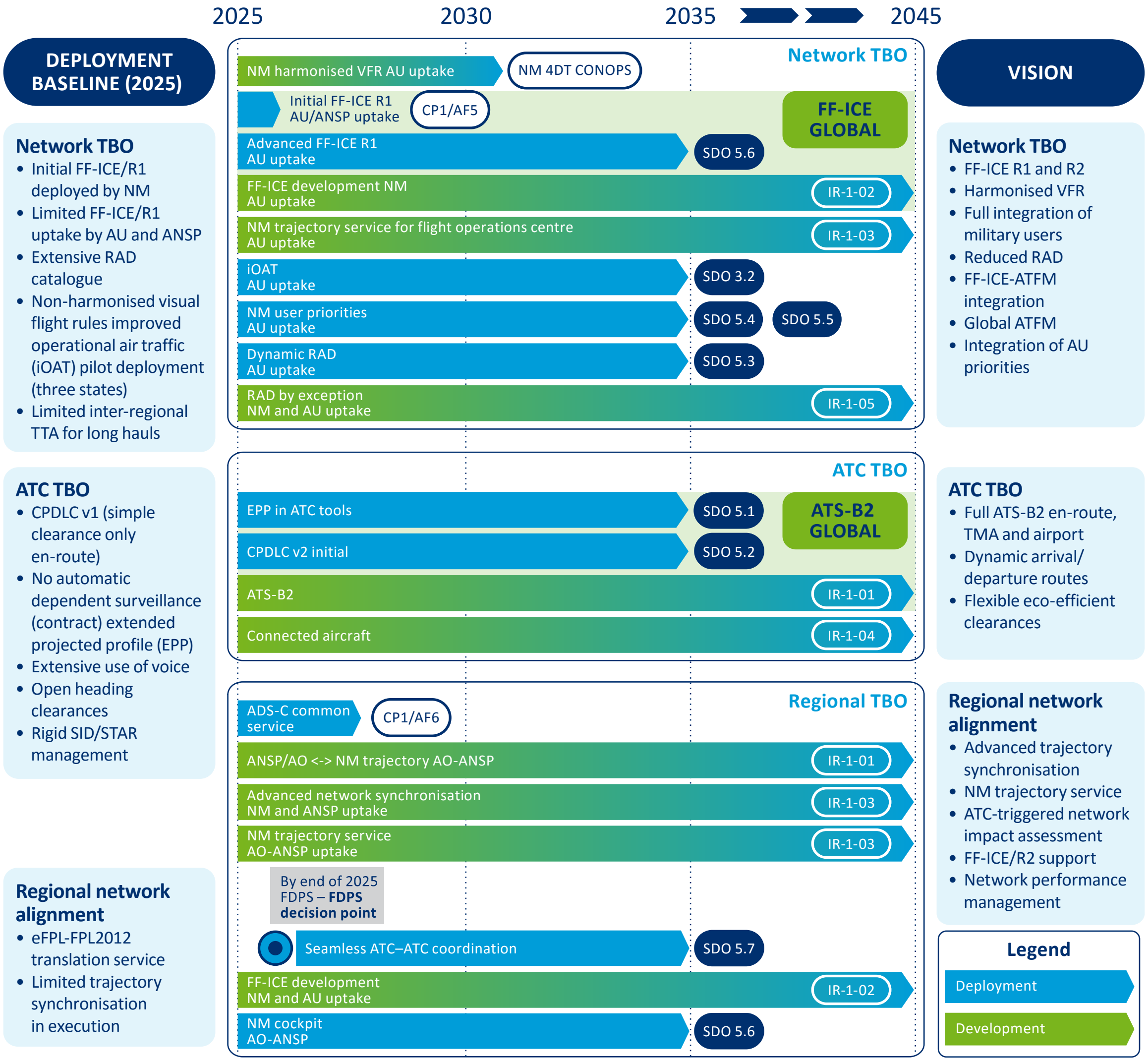

FIGURE 19: INTEGRATED TBO ROADMAP

A.2 CNS roadmap

The roadmap in Figure 20 covers communication, navigation and surveillance (CNS) functionalities that need to be developed and deployed to implement the vision. The ATM system will gradually evolve into one lean and efficient CNS infrastructure with state-of-the-art technology. The roadmap considers the target architecture and service delivery model, which seeks to enable much higher levels of connectivity and automation of systems on the ground and in the air than today. It also outlines, where possible, opportunities for the convergence of the ATM and U-space environments, and rationalisations that should be considered during the transition between the current and future CNS infrastructure. Finally, the roadmap integrates and refines the recent work of the CNS Advisory Group (69), civil–military synergies and the White Paper on future connectivity in aviation (70).

This roadmap will be complemented by a CNS Evolution Plan, which is under development by the CNS Programme Manager function, executed by the Network Manager. The plan will provide more details on the modernisation of European CNS infrastructure, addressing how best to deploy strategic priorities defined in the ATM Master Plan. It will detail the rationale and timelines for the deployment of new ground infrastructure, on which the synchronised evolution of the relevant ground and airborne certification specifications and EU deployment mandates can be based, as well as options for the decommissioning and removal of equipment assessed as surplus to resilience principles still to be defined at the network and national levels. The CNS Programme Manager may make recommendations to be considered in regulatory or policy intervention, which will remain subject to the relevant institutional regulatory and rule-making process.

Vision and key milestones for CNS

By 2030, the number of required navigation performance (RNP) approaches and precision approach procedures will significantly increase, and the transition towards high-performance air–ground connectivity (a successor of very-high-frequency data link mode 2 (VDL-M2) will be under way. Significant progress will have been made on development priorities affecting CNS, such as the use by future ground platforms of CNS data as a service.

By 2035, a minimum operational network (MON) will have been implemented in Europe to fully optimise the infrastructure where possible and address vulnerabilities such as system failures, electromagnetic interferences, jamming, spoofing and ionospheric propagation disturbances.

By 2045, voice communication will no longer be the primary means of communication, as most routine tasks will be managed through machine–machine applications. Infrastructure on the ground, in the air and in space will be used effectively to deliver CNS as a service. The service will be contracted between customers and providers with a clearly established set of Europe-wide harmonised services and a level of quality that enables the optimisation of trajectories for all users of the sky (civil and military). Ground-based augmentation systems (GBAS) leveraging Galileo will serve category (CAT) II/III operations currently relying on instrument landing systems (ILS), and GNSS capabilities will be fully leveraged to allow innovative air mobility (IAM) users to operate effectively, providing robust capabilities against jamming and spoofing (leveraging Galileo Open Service Navigation Message Authentication (OSNMA)).

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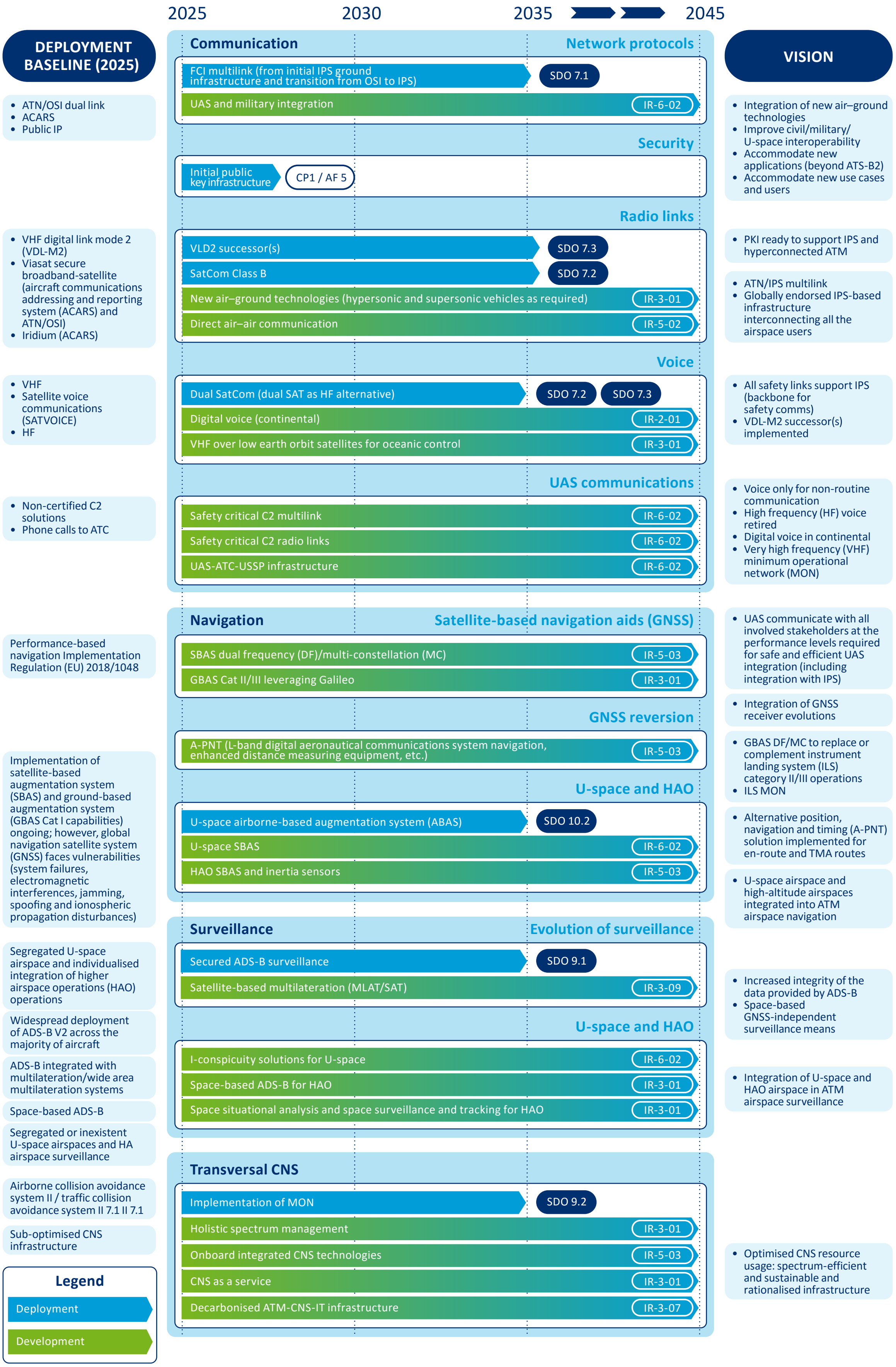
69 Composed of experts from the European Commission; EASA; Eurocontrol; SESAR 3 JU; the SESAR Deployment Manager; the European Defence Agency and EUROCAE; CANSO; the International Air Transport Association and the European Business Aviation Association, representing airspace users; Airports Council International; the Expert Group on the Human Dimension of the Single European Sky; and the Industry Consultation Body.

70 EASA, Future Connectivity for Aviation, White Paper.



2025 | 2030 | 2035 | 2045

DEPLOYMENT BASELINE (2025)

VISION

Communication

Network protocols

Deployment baseline:
- ATN/OSI dual link
- ACARS
- Public IP

- FCI multilink (from initial IPS ground infrastructure and transition from OSI to IPS) — SDO 7.1
- UAS and military integration — IR-6-02

Vision:
- Integration of new air–ground technologies
- Improve civil/military/U-space interoperability
- Accommodate new applications (beyond ATS-B2)
- Accommodate new use cases and users

Security

- Initial public key infrastructure — CP1 / AF 5

Vision:
- PKI ready to support IPS and hyperconnected ATM

Radio links

Deployment baseline:
- VHF digital link mode 2 (VDL-M2)
- Viasat secure broadband-satellite (aircraft communications addressing and reporting system (ACARS) and ATN/OSI)
- Iridium (ACARS)

- VLD2 successor(s) — SDO 7.3
- SatCom Class B — SDO 7.2
- New air–ground technologies (hypersonic and supersonic vehicles as required) — IR-3-01
- Direct air–air communication — IR-5-02

Vision:
- ATN/IPS multilink
- Globally endorsed IPS-based infrastructure interconnecting all the airspace users

Voice

Deployment baseline:
- VHF
- Satellite voice communications (SATVOICE)
- HF

- Dual SatCom (dual SAT as HF alternative) — SDO 7.2 — SDO 7.3
- Digital voice (continental) — IR-2-01
- VHF over low earth orbit satellites for oceanic control — IR-3-01

Vision:
- All safety links support IPS (backbone for safety comms)
- VDL-M2 successor(s) implemented

UAS communications

Deployment baseline:
- Non-certified C2 solutions
- Phone calls to ATC

- Safety critical C2 multilink — IR-6-02
- Safety critical C2 radio links — IR-6-02
- UAS-ATC-USSP infrastructure — IR-6-02

Vision:
- Voice only for non-routine communication
- High frequency (HF) voice retired
- Digital voice in continental
- Very high frequency (VHF) minimum operational network (MON)

Navigation

Satellite-based navigation aids (GNSS)

Deployment baseline: Performance-based navigation Implementation Regulation (EU) 2018/1048

- SBAS dual frequency (DF)/multi-constellation (MC) — IR-5-03
- GBAS Cat II/III leveraging Galileo — IR-3-01

Vision:
- UAS communicate with all involved stakeholders at the performance levels required for safe and efficient UAS integration (including integration with IPS)
- Integration of GNSS receiver evolutions

GNSS reversion

Deployment baseline: Implementation of satellite-based augmentation system (SBAS) and ground-based augmentation system (GBAS Cat I capabilities) ongoing; however, global navigation satellite system (GNSS) faces vulnerabilities (system failures, electromagnetic interferences, jamming, spoofing and ionospheric propagation disturbances)

- A-PNT (L-band digital aeronautical communications system navigation, enhanced distance measuring equipment, etc.) — IR-5-03

Vision:
- GBAS DF/MC to replace or complement instrument landing system (ILS) category II/III operations
- ILS MON

U-space and HAO

Deployment baseline: Segregated U-space airspace and individualised integration of higher airspace operations (HAO) operations

- U-space airborne-based augmentation system (ABAS) — SDO 10.2
- U-space SBAS — IR-6-02
- HAO SBAS and inertia sensors — IR-5-03

Vision:
- Alternative position, navigation and timing (A-PNT) solution implemented for en-route and TMA routes
- U-space airspace and high-altitude airspaces integrated into ATM airspace navigation

Surveillance

Evolution of surveillance

Deployment baseline:
- Widespread deployment of ADS-B V2 across the majority of aircraft
- ADS-B integrated with multilateration/wide area multilateration systems
- Space-based ADS-B

- Secured ADS-B surveillance — SDO 9.1
- Satellite-based multilateration (MLAT/SAT) — IR-3-09

Vision:
- Increased integrity of the data provided by ADS-B
- Space-based GNSS-independent surveillance means

U-space and HAO

Deployment baseline: Segregated or inexistent U-space airspaces and HA airspace surveillance

- I-conspicuity solutions for U-space — IR-6-02
- Space-based ADS-B for HAO — IR-3-01
- Space situational analysis and space surveillance and tracking for HAO — IR-3-01

Vision:
- Integration of U-space and HAO airspace in ATM airspace surveillance

Transversal CNS

Deployment baseline:
- Airborne collision avoidance system II / traffic collision avoidance system II 7.1 II 7.1
- Sub-optimised CNS infrastructure

- Implementation of MON — SDO 9.2
- Holistic spectrum management — IR-3-01
- Onboard integrated CNS technologies — IR-5-03
- CNS as a service — IR-3-01
- Decarbonised ATM-CNS-IT infrastructure — IR-3-07

Vision:
- Optimised CNS resource usage: spectrum-efficient and sustainable and rationalised infrastructure

Legend

🟦	Deployment
🟩	Development

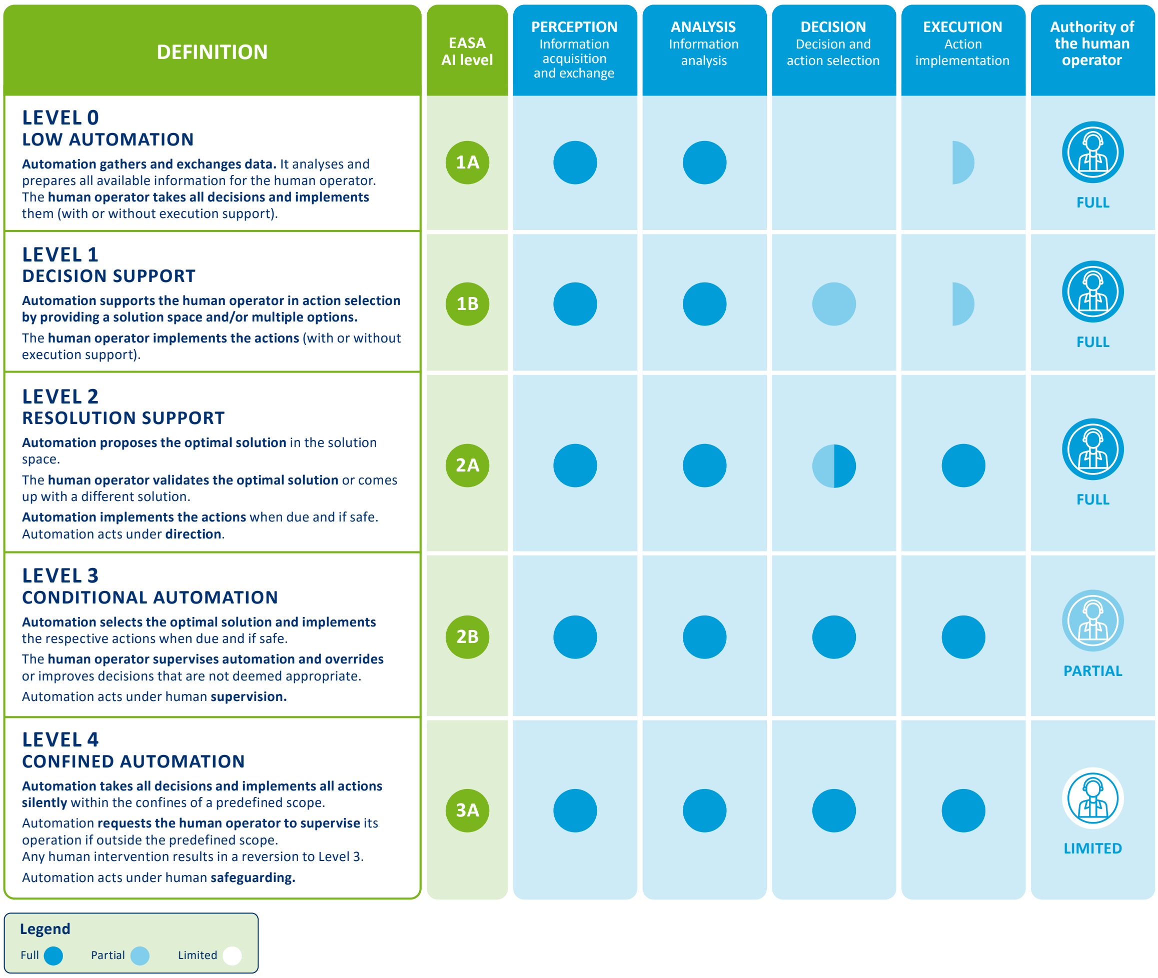
FIGURE 20: CNS ROADMAP

A.3 Automation roadmap

This roadmap covers automation functionalities that need to be developed and deployed to enable human–machine teaming, as outlined in the vision. The aim is that operations in certain phases of flight will be fully automated, whereby automation is capable of managing both nominal and non-nominal situations. In this new paradigm, the role of humans will evolve significantly, focusing on the tasks or situations too complex for automation to handle, teaming up with automation to address increasing traffic complexity. Voice will no longer be the primary means of communication, as routine tasks are managed through machine–machine applications.

For simple tasks and situations, high levels of automation are achievable without AI, while it is expected that the automation of more complex tasks will require AI. The EASA artificial intelligence roadmap 2.0 provides an AI trustworthiness framework for enabling readiness for use of AI in aviation, defining six levels of AI based on the level of human agency and oversight of the AI-based application.

The targeted automation levels for ATM are expressed as future system capabilities, which should gradually enable air traffic service providers to handle flights in automated ways within a predefined scope. Outside this scope (when a task or a situation becomes too complex for automation to handle), automation will request the human operator to supervise its operation, as illustrated in Figure 21. For each level of automation, the figure indicates the applicable AI level of EASA, where the level of automation is achieved using AI.



DEFINITION	EASA AI level	PERCEPTION Information acquisition and exchange	ANALYSIS Information analysis	DECISION Decision and action selection	EXECUTION Action implementation	Authority of the human operator
LEVEL 0 **LOW AUTOMATION** **Automation gathers and exchanges data.** It analyses and prepares all available information for the human operator. The **human operator takes all decisions and implements** them (with or without execution support).	1A	●	●		◗	FULL
LEVEL 1 **DECISION SUPPORT** **Automation supports the human operator in action selection by providing a solution space and/or multiple options.** The **human operator implements the actions** (with or without execution support).	1B	●	●	◉	◗	FULL
LEVEL 2 **RESOLUTION SUPPORT** **Automation proposes the optimal solution** in the solution space. The **human operator validates the optimal solution** or comes up with a different solution. **Automation implements the actions** when due and if safe. Automation acts under **direction**.	2A	●	●	◑	●	FULL
LEVEL 3 **CONDITIONAL AUTOMATION** **Automation selects the optimal solution and implements** the respective actions when due and if safe. The **human operator supervises automation and overrides** or improves decisions that are not deemed appropriate. Automation acts under human **supervision.**	2B	●	●	●	●	PARTIAL
LEVEL 4 **CONFINED AUTOMATION** **Automation takes all decisions and implements all actions silently** within the confines of a predefined scope. Automation **requests the human operator to supervise** its operation if outside the predefined scope. Any human intervention results in a reversion to Level 3. Automation acts under human **safeguarding.**	3A	●	●	●	●	LIMITED

Legend
Full ● Partial ◉ Limited ○

FIGURE 21: LEVELS OF AUTOMATION TAXONOMY AND CORRESPONDENCE TO EASA AI LEVELS

The human actors in the roles and functions of the ATM system will evolve in line with the paradigm shift envisaged by the implementation of the vision. New roles and functions will emerge; existing roles and functions will change, in some cases radically, whereby humans become 'system components' in joint and distributed cognitive systems, and humans and automation share responsibility for ensuring safety and efficiency. Automation support will also make it possible for controllers to provide services across a wider geographical area than was previously possible, with controllers' competence being linked to their ability to operate the system efficiently rather than to specific sectors. The controller licensing schemes, and the ATM system certification framework, will evolve to support this new way of operating. Automation will be developed to the extent that situations can be handled as well as or better than when the human is involved, including full decision-making and action implementation.

The different levels of human roles are as follows:

- **Enhanced decision-maker (level 1).** The human makes all decisions based on the appropriate overviews of all feasible options (e.g. solution space) provided by automation.
- **Director (level 2).** The human evaluates the optimal solution provided by automation and improves it where necessary. The human has the final say, while automation performs all the calculations necessary to support decision-making.
- **Supervisor (level 3).** The human decides which tasks/situations are to be managed by the automation and by themselves. For instance, the human air traffic controller decides which aircraft should be guided by automation. The human controller oversees and can override automation once a system's decision is not deemed appropriate due to a particular operational understanding that is not known to automation.
- **Safeguarder (level 4).** The system operates fully autonomously under the supervision of the human. When the system identifies that it is at risk of operating outside its allocated operational design parameters, it suggests moving back to level 3 or lower.

The design of the next generation of ATM systems in this highly automated environment will aim to achieving a human–machine teaming. The trade-off between augmentation and assistance will be carefully balanced to avoid information overload. Technology-specific and operational metrics will be used to track system performance in both the short and the long term, with particular attention being paid to the early detection of degradation modes through leading indicators.

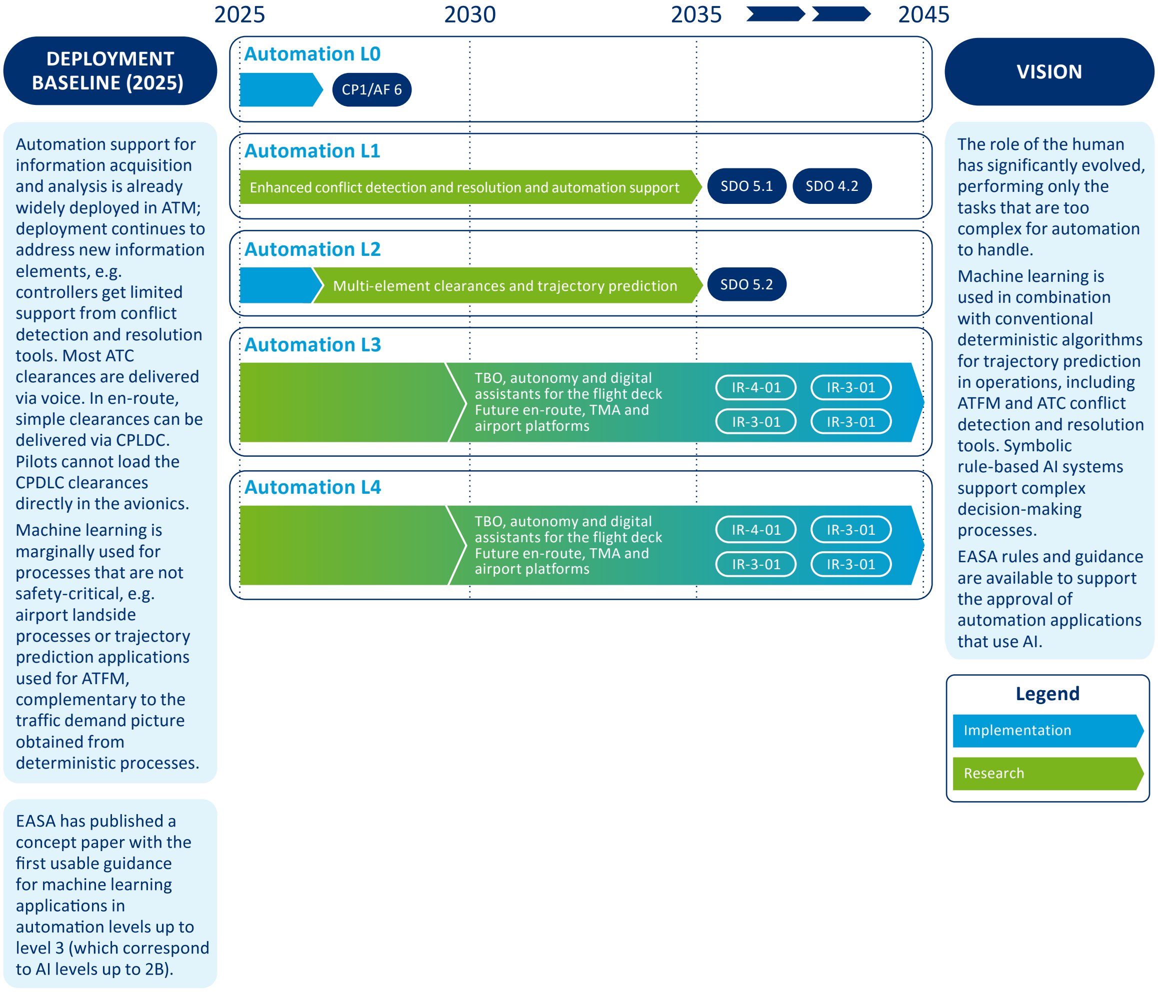
The ATM workforce will be involved in the design of the new ATM platforms from the early stages. System development will incorporate the well-established SESAR methodology to include iterative verification and validation, in which systems are tested by end users in isolation as well as in an integrated setting, and all relevant human performance metrics are carefully monitored. Service orientation principles will be applied at all levels to facilitate the updating of the system in both its development and its operational phases, allowing the incorporation of user feedback and providing flexibility to address emerging operational needs. Human performance expectations and responsibilities will be clearly identified and commensurate with human capabilities and limitations. The integration of AI in ATM systems will be designed to be interpretable to operators. Human competence schemes will evolve to ensure that controllers and air traffic safety electronics personnel (ATSEPs) gain and retain the appropriate skills, including relevant expert-user-level understanding of AI methodologies.

Vision and key milestones for automation

By 2030, ATM in Europe will operate at automation level 0, with progressive introduction of AI, in particular machine learning applications for supporting ATFM, ATC operations or airport landside processes (Figure 22). Significant progress will have been achieved on the development of future en-route, TMA and airport platforms designed for automation level 2 and above.

By 2035, ATM in Europe will operate at automation level 2 thanks to the implementation of increased automation support tools and the transition to TBO phase 2. This will have been achieved with the implementation of sector team configurations, automatic speech recognition, user profile management, attention guidance and trajectory prediction tools supporting the early detection and resolution of potential conflicts.

By 2045, for certain phases of flight, ATM in Europe will operate at automation level 4 (or when needed at lower levels when outside a predefined scope for level 4) thanks to the implementation of new platforms designed for human–machine teaming. Voice communication will no longer be the primary means of communication, as most routine tasks will be managed through machine–machine applications.



Automation support for information acquisition and analysis is already widely deployed in ATM; deployment continues to address new information elements, e.g. controllers get limited support from conflict detection and resolution tools. Most ATC clearances are delivered via voice. In en-route, simple clearances can be delivered via CPLDC. Pilots cannot load the CPDLC clearances directly in the avionics.

Machine learning is marginally used for processes that are not safety-critical, e.g. airport landside processes or trajectory prediction applications used for ATFM, complementary to the traffic demand picture obtained from deterministic processes.

EASA has published a concept paper with the first usable guidance for machine learning applications in automation levels up to level 3 (which correspond to AI levels up to 2B).

The role of the human has significantly evolved, performing only the tasks that are too complex for automation to handle.

Machine learning is used in combination with conventional deterministic algorithms for trajectory prediction in operations, including ATFM and ATC conflict detection and resolution tools. Symbolic rule-based AI systems support complex decision-making processes.

EASA rules and guidance are available to support the approval of automation applications that use AI.

FIGURE 22: AUTOMATION ROADMAP

A.4 U-space 2.0 roadmap

The roadmap in Figure 23 covers U-space 2.0 functionalities, which need to be developed and deployed to implement the vision in which the ATM system gradually evolves to cater for the uptake of innovative air mobility (IAM). The roadmap includes the overall refinement of the concept of U-space to better reflect latest developments and insights that impact the definition and roll-out of U1 and U2 services. It also reflects the latest developments and needs of IAM that impact the definition and roll-out of U3 and U4 services. Where feasible, the roadmap also takes into account the specific needs of general aviation (GA) and rotorcraft that could be addressed through U-space services.

Vision and key milestones for U-space 2.0

By 2030, U-space U1 and U2 services will be implemented in Europe and the first IAM/VTOL capable aircraft (VCA) operations will be accommodated like any other rotorcraft operation. Significant progress will have been made on development priorities related to U3 and U4 services, such as enabling IAM/VCA (crewed and uncrewed) operations at scale, including in complex environments, congested portions of airspace and vertiports.

By 2035, a common ATM/U-space interface, dynamic airspace reconfiguration service and new GNSS-enabled procedures will be implemented to allow IAM users to operate to and from airports/vertiports and TMAs without conflicting with other traffic.

By 2045, thanks to the implementation of U-space U3 and U4 services, as well as future en-route, TMA and airport platforms, ATM and U-space will enable the seamless integration of crewed and uncrewed vehicles in all classes of airspace.

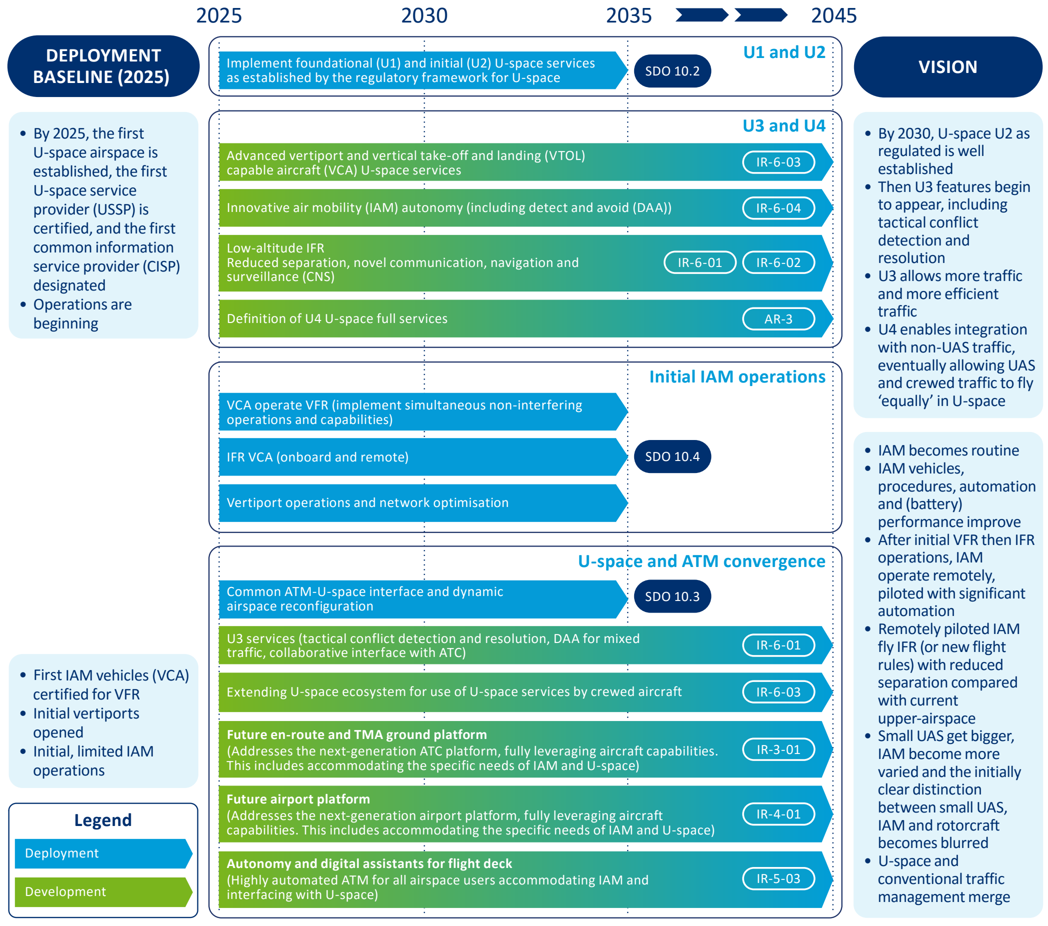


FIGURE 23: U-SPACE 2.0 ROADMAP

A.5 Civil–Military roadmap

The roadmap in Figure 24 identifies priority civil–military capabilities (i.e. in terms of airspace, technology and data), which need to be developed and deployed to ensure the progressive airspace integration of envisaged future combat systems, including remotely piloted air systems (RPAS), in an interoperable manner and with additional efforts to ensure the robustness and resilience of cybersecurity. The air domain is critical to securing EU territories and their populations, as well as for international trade and travel. Effective civil–military cooperation, as reflected in this roadmap, is key to enhancing flight efficiency, optimising airspace capacity and safeguarding the military's operational efficiency, as well as the effectiveness of military mission (i.e. planning versus activation). This cooperation is also critical for facilitating access to airspace for new military aerial vehicles (e.g. fifth-generation fighters, RPAS, high-altitude pseudo-satellites and balloons) in a sustainable, safe and secure aviation environment.

Military operations require unlimited access to airspace and airports with the support of a dual-use CNS infrastructure. Such CNS systems will accommodate military flights with required levels of air–ground two-way communication, high levels of advanced navigation steering and positioning, and surveillance identification and separation – in all cases with a high level of security and resilience. Connectivity through SWIM, access to data repositories and participation in TBO are essential.

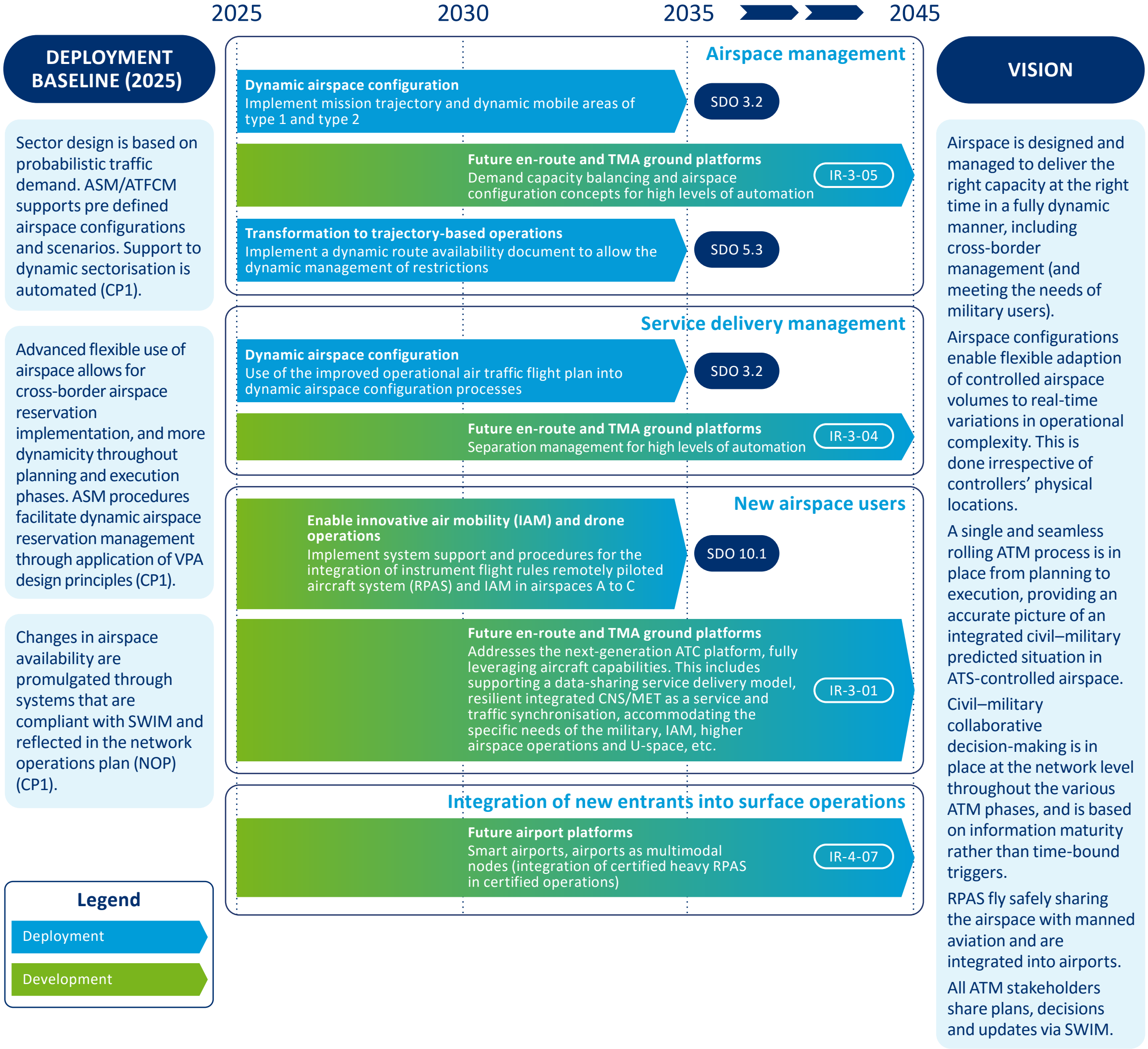
Vision and key milestones for civil–military capabilities

By 2030, enhanced data sharing will be facilitated by predefined airspace structures, enabling more dynamic airspace management and free route airspace. This process necessitates higher levels of coordination between civil and military air navigation service providers (ANSPs), supported by dynamic civil–military collaborative decision-making (CDM). Significant progress will have been made on development priorities affecting air–ground connectivity (including CNS dual use) and the level of automation for future en-route, TMA and airport platforms (including the fully dynamic management of scalable airspace configurations to meet the needs of military users).

By 2035, the implementation of mission trajectory and dynamic mobile areas (DMAs) of types 1 and 2 will be completed, using the improved operational air traffic flight plan (iOAT) in dynamic airspace configuration processes, together with integration of instrument flight rules (IFR) RPAS into airspace classes A to C.

By 2045, all missions (crewed or uncrewed) – including those by supersonic, hypersonic and suborbital vehicles – will operate in a way that maximises to the fullest extent, aircraft capabilities to reduce the overall impact of aviation on the climate. Airspace will be designed and managed to deliver the right capacity at the right time in a fully dynamic manner, including cross-border management. A single and seamless rolling ATM process will be in place from planning to execution, providing an accurate picture of an integrated civil–military predicted situation in ATS-controlled airspace. Civil–military collaborative decision-making will be in place at the network level throughout the various ATM phases, based on information maturity rather than time bound.

With these developments, civil ANSPs in collaboration with the military can dynamically scale capacity up or down in line with demand while also taking into account military users. These capacity adjustments are implemented in real time and ensure an optimal and cost-efficient use of resources at any moment across the network (airspace, data, infrastructure and human–machine teaming). The continuous optimisation of every mission trajectory will also improve the civil use of released and available airspace (CURA) thanks to high connectivity between air–ground and ground–ground components.



2025 2030 2035 2045

DEPLOYMENT BASELINE (2025)

Sector design is based on probabilistic traffic demand. ASM/ATFCM supports pre defined airspace configurations and scenarios. Support to dynamic sectorisation is automated (CP1).

Advanced flexible use of airspace allows for cross-border airspace reservation implementation, and more dynamicity throughout planning and execution phases. ASM procedures facilitate dynamic airspace reservation management through application of VPA design principles (CP1).

Changes in airspace availability are promulgated through systems that are compliant with SWIM and reflected in the network operations plan (NOP) (CP1).

Airspace management

Dynamic airspace configuration
Implement mission trajectory and dynamic mobile areas of type 1 and type 2
SDO 3.2

Future en-route and TMA ground platforms
Demand capacity balancing and airspace configuration concepts for high levels of automation
IR-3-05

Transformation to trajectory-based operations
Implement a dynamic route availability document to allow the dynamic management of restrictions
SDO 5.3

Service delivery management

Dynamic airspace configuration
Use of the improved operational air traffic flight plan into dynamic airspace configuration processes
SDO 3.2

Future en-route and TMA ground platforms
Separation management for high levels of automation
IR-3-04

New airspace users

Enable innovative air mobility (IAM) and drone operations
Implement system support and procedures for the integration of instrument flight rules remotely piloted aircraft system (RPAS) and IAM in airspaces A to C
SDO 10.1

Future en-route and TMA ground platforms
Addresses the next-generation ATC platform, fully leveraging aircraft capabilities. This includes supporting a data-sharing service delivery model, resilient integrated CNS/MET as a service and traffic synchronisation, accommodating the specific needs of the military, IAM, higher airspace operations and U-space, etc.
IR-3-01

Integration of new entrants into surface operations

Future airport platforms
Smart airports, airports as multimodal nodes (integration of certified heavy RPAS in certified operations)
IR-4-07

VISION

Airspace is designed and managed to deliver the right capacity at the right time in a fully dynamic manner, including cross-border management (and meeting the needs of military users).

Airspace configurations enable flexible adaption of controlled airspace volumes to real-time variations in operational complexity. This is done irrespective of controllers' physical locations.

A single and seamless rolling ATM process is in place from planning to execution, providing an accurate picture of an integrated civil–military predicted situation in ATS-controlled airspace.

Civil–military collaborative decision-making is in place at the network level throughout the various ATM phases, and is based on information maturity rather than time-bound triggers.

RPAS fly safely sharing the airspace with manned aviation and are integrated into airports.

All ATM stakeholders share plans, decisions and updates via SWIM.

Legend

🟦	Deployment
🟩	Development

FIGURE 24: CIVIL–MILITARY ROADMAP

A.6 Cybersecurity capabilities roadmap

The roadmap in Figure 25 defines priority cybersecurity capabilities, which need to be developed and deployed to enhance the cybersecurity posture of ATM systems, protecting critical infrastructure, data and operations from cyberthreats.

As described by the vision, future ATM will rely on increased information flows between more stakeholders and higher levels of automation, all against a backdrop of an increasingly hostile environment prone to cyberattacks. A homogeneous and holistic approach to security risk management will be critical to tackling increased exposure to cyberthreats and ensuring cyber-resilience. This will allow interconnected components to trust the information flow they receive. Effective and efficient risk management, using the latest updated security risk assessment methodology (SECRAM) and threat catalogue, will be based on identifying the risks associated with any compromise of key security attributes: confidentiality, integrity, availability, authenticity and non-repudiation.

An oversight mechanism will be implemented, enabling the evaluation of security risk assessments, applied consistently among SESAR Solutions.

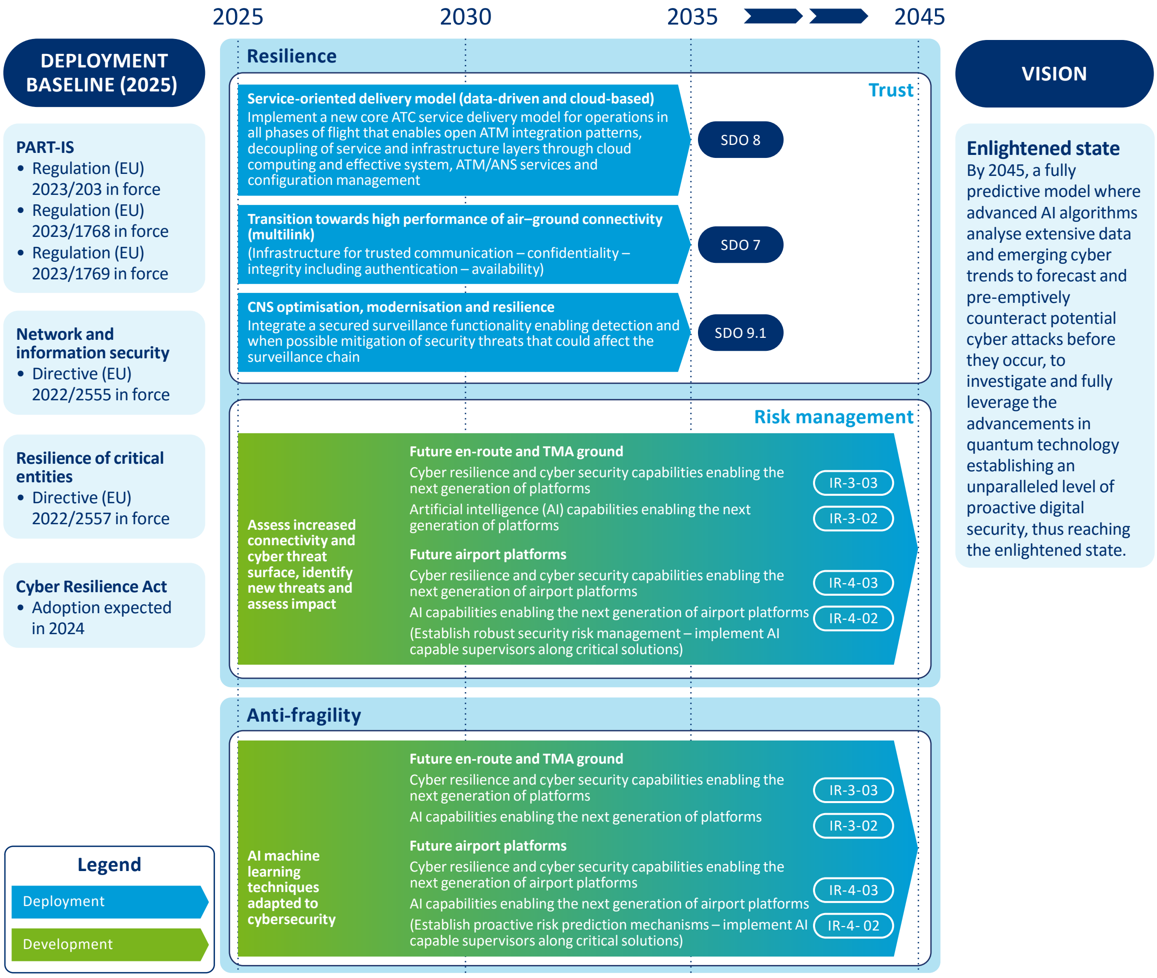
Once the appropriate risk level is established for each security attribute, specific security requirements can be identified. For example, a strong digital signature mechanism may be necessary for high-integrity requirements, while a simple checksum may suffice for low-integrity needs. Similarly, with regard to confidentiality, a medium level of risk may require encryption with a standard algorithm, while a high level of risk would necessitate using advanced encryption methods and stricter access controls. In this way, a secure and trusted communication infrastructure will be available.

Vision and key milestones for cybersecurity capabilities

By 2030, the European aviation ecosystem will be **resilient** to cyberthreats. It will maintain its ability to deliver the intended outcome continuously, even when regular delivery mechanisms are under cyberattack.

By 2035, the European aviation ecosystem will transition from resilience to a state of **anti-fragility**, where its cybersecurity infrastructure actively learns from attacks and becomes stronger in the face of new threats, ensuring a safer and adaptive aviation ecosystem. This approach relies on proactive systems that not only withstand attacks and disruptions but also evolve to anticipate and neutralise future cyber risks, thereby enhancing the overall security and reliability of European aviation.

By 2045, European aviation cybersecurity reaches the **enlightened** state, a fully predictive model in which advanced AI algorithms analyse extensive data and emerging cyber trends to forecast and pre-emptively counteract potential cyberattacks before they occur, establishing an unparalleled level of proactive digital security.



DEPLOYMENT BASELINE (2025)

PART-IS
- Regulation (EU) 2023/203 in force
- Regulation (EU) 2023/1768 in force
- Regulation (EU) 2023/1769 in force

Network and information security
- Directive (EU) 2022/2555 in force

Resilience of critical entities
- Directive (EU) 2022/2557 in force

Cyber Resilience Act
- Adoption expected in 2024

Resilience

Trust

Service-oriented delivery model (data-driven and cloud-based)
Implement a new core ATC service delivery model for operations in all phases of flight that enables open ATM integration patterns, decoupling of service and infrastructure layers through cloud computing and effective system, ATM/ANS services and configuration management — SDO 8

Transition towards high performance of air–ground connectivity (multilink)
(Infrastructure for trusted communication – confidentiality – integrity including authentication – availability) — SDO 7

CNS optimisation, modernisation and resilience
Integrate a secured surveillance functionality enabling detection and when possible mitigation of security threats that could affect the surveillance chain — SDO 9.1

Risk management

Assess increased connectivity and cyber threat surface, identify new threats and assess impact

Future en-route and TMA ground
Cyber resilience and cyber security capabilities enabling the next generation of platforms — IR-3-03
Artificial intelligence (AI) capabilities enabling the next generation of platforms — IR-3-02

Future airport platforms
Cyber resilience and cyber security capabilities enabling the next generation of airport platforms — IR-4-03
AI capabilities enabling the next generation of airport platforms — IR-4-02
(Establish robust security risk management – implement AI capable supervisors along critical solutions)

Anti-fragility

AI machine learning techniques adapted to cybersecurity

Future en-route and TMA ground
Cyber resilience and cyber security capabilities enabling the next generation of platforms — IR-3-03
AI capabilities enabling the next generation of platforms — IR-3-02

Future airport platforms
Cyber resilience and cyber security capabilities enabling the next generation of airport platforms — IR-4-03
AI capabilities enabling the next generation of airport platforms
(Establish proactive risk prediction mechanisms – implement AI capable supervisors along critical solutions) — IR-4- 02

VISION

Enlightened state
By 2045, a fully predictive model where advanced AI algorithms analyse extensive data and emerging cyber trends to forecast and pre-emptively counteract potential cyber attacks before they occur, to investigate and fully leverage the advancements in quantum technology establishing an unparalleled level of proactive digital security, thus reaching the enlightened state.

Legend
- 🟦 Deployment
- 🟩 Development

FIGURE 25: CYBERSECURITY CAPABILITIES ROADMAP

A.7 New service delivery model – business services

Table 17 presents the list of business services for a typical area control centre (ACC).

Business service	Examples of functions covered by the business service (*)
Human–machine interface (HMI)	Air situation display, alerts, flight editing and dialogue, attention and fatigue, speech recognition.
Flight data/trajectory management	4D trajectory prediction, ATC–ATC exchanges, ATC–NM exchanges, flight correlation, secondary surveillance radar (SSR) code management, flight plan correction, performance management.
Sequencing	Arrival management, departure management, integrated arrival–departure management (AMAN-DMAN), time-based separation.
Separation management	Tactical controller tools, conflict detection, conflict resolution and assistance, 'what if–what else' probing, adherence monitoring, merging and spacing.
Local air traffic flow and capacity management (ATFCM)	Local demand and capacity balancing (DCB), complexity management.
Safety nets	Short-term conflict alerts (STCA), minimum safe altitude warnings (MSAW), area proximity warnings (APW), approach path monitoring (APM), ground safety nets.
Navigation	Navigation signals, performance monitoring.
Communication	Ground–ground voice communication, air–ground voice communication, voice control distribution, voice control management, performance monitoring.
Surveillance	Surveillance data fusion, tracking, surveillance data distribution, surveillance sensors, performance monitoring.
Data link	Controller pilot data link communications (CPDLC); automatic dependent surveillance – contract (ADS-C), including extended projected profiles (EPP); context management; downlinked aircraft parameters (DAP), including humidity.
Environment (CO_2/non-CO_2)	CO_2 emissions; non-CO_2 emissions, including contrail management; noise.
Civil–military airspace management	Airspace reservation management (ARES), booking management, airspace configuration and distribution, airspace status distribution.
Operational supervision	Sector configuration, configuration of parameters, operational supervision distribution.
CNS infrastructure and basic services	Deployment, recording, time synchronisation, metrics and reports, logging, voice over internet protocol (VoIP), monitoring, billing.
Network services	Pan-European network service (PENS), ATS common data link services (ACDLS), future communications infrastructure (FCI), system-wide information management (SWIM) yellow profile.
Simulation, training and analysis services	Traffic generator, preparation and execution, pseudo-pilots, replay function.
Meteorology	Operational meteorological information (OPMET), local weather, convection, winds, clear air turbulence, icing, space weather.
Aeronautical information management	Aeronautical information publication (AIP), aeronautical information circular (AIC), notice to airmen (NOTAM), digital notice to airmen (D-NOTAM), aeronautical information management (AIM) on request, charting, charting on request.

* The examples are indicative only; they may not be complete and may be subject to change.

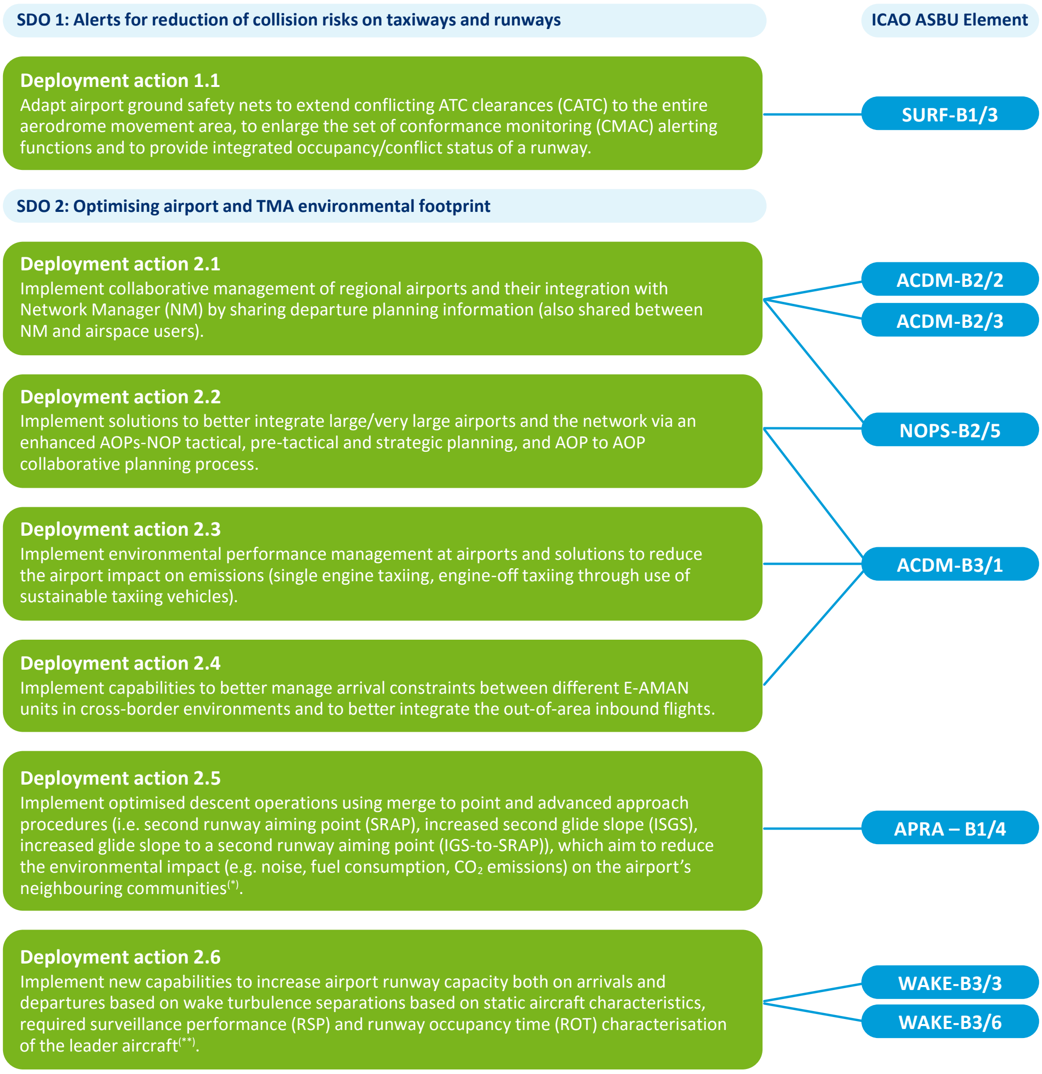
TABLE 17: BUSINESS SERVICES FOR A TYPICAL ACC

A.8 Mapping the Master Plan against the GANP

This appendix maps the Master Plan to the seventh edition of the ICAO's global air navigation plan (GANP). The Master Plan and the GANP are complementary, with the Master Plan focusing on the European context, while the GANP provides a global framework, ensuring consistency and collaboration across regions. It is therefore important to demonstrate that the European ATM Master Plan aligns with the global objectives set by the GANP.

As the content of the GANP is organised into a multilayer structure, with each layer tailored to different audiences, the mapping relates the deployment actions of the SDOs to the global technical level (level 2) of the GANP. The global technical level supports technical managers in planning the implementation of basic services and new operational improvements in a cost-effective manner and according to specific needs, while ensuring the interoperability of systems and the harmonisation of procedures. One of the key building blocks of the global technical level are aviation system block upgrade (ASBU) elements that describe specific operational improvements. ASBU elements are organised in ASBU threads that correspond to key features of the air navigation system. In Table 18, for every SDO, a one-to-many mapping was established between deployment actions and ASBU elements, where available.

The ICAO's ASBU panel project team is currently preparing the eighth edition of the GANP, to which this Master Plan brings significant input.



SDO 1: Alerts for reduction of collision risks on taxiways and runways

ICAO ASBU Element

Deployment action 1.1
Adapt airport ground safety nets to extend conflicting ATC clearances (CATC) to the entire aerodrome movement area, to enlarge the set of conformance monitoring (CMAC) alerting functions and to provide integrated occupancy/conflict status of a runway.

SURF-B1/3

SDO 2: Optimising airport and TMA environmental footprint

Deployment action 2.1
Implement collaborative management of regional airports and their integration with Network Manager (NM) by sharing departure planning information (also shared between NM and airspace users).

ACDM-B2/2

ACDM-B2/3

NOPS-B2/5

Deployment action 2.2
Implement solutions to better integrate large/very large airports and the network via an enhanced AOPs-NOP tactical, pre-tactical and strategic planning, and AOP to AOP collaborative planning process.

ACDM-B3/1

Deployment action 2.3
Implement environmental performance management at airports and solutions to reduce the airport impact on emissions (single engine taxiing, engine-off taxiing through use of sustainable taxiing vehicles).

Deployment action 2.4
Implement capabilities to better manage arrival constraints between different E-AMAN units in cross-border environments and to better integrate the out-of-area inbound flights.

Deployment action 2.5
Implement optimised descent operations using merge to point and advanced approach procedures (i.e. second runway aiming point (SRAP), increased second glide slope (ISGS), increased glide slope to a second runway aiming point (IGS-to-SRAP)), which aim to reduce the environmental impact (e.g. noise, fuel consumption, CO_2 emissions) on the airport's neighbouring communities(*).

APRA – B1/4

Deployment action 2.6
Implement new capabilities to increase airport runway capacity both on arrivals and departures based on wake turbulence separations based on static aircraft characteristics, required surveillance performance (RSP) and runway occupancy time (ROT) characterisation of the leader aircraft(**).

WAKE-B3/3

WAKE-B3/6

* No ICAO element yet for ISGS, SRAP, IGS-to-SRAP – possibility to be in the next version of the GANP.

** An ASBU APTA-B3/X related to DA 2.6 will possibly be included in the next version of the GANP.

SDO 3: Dynamic airspace configuration	**ICAO ASBU Element**
Deployment action 3.1 Implement higher levels of granularity and dynamicity in airspace configurations, adjusted to traffic demand and military needs for airspace reservations, enabling cross-border coordination between all civil and military actors.	FRTO-B2/1 FRTO-B2/2 NOPS-B2/2
Deployment action 3.2 Implement mission trajectory and dynamic mobile areas (DMAs) of type 1 and type 2 using the improved operational air traffic flight plan (iOAT FPL) into dynamic airspace configuration processes in the medium- to short-term ATM planning phase to support military airspace requirements.	FRTO-B1/3 FRTO-B2/2
SDO 4: Increased automation support	
Deployment action 4.1 Implement sector team configurations which in specific airspace configurations include the combination of one planning ATCO with two tactical/executive ATCOs in an en-route/eTMA environment.	FRTO-B1/6
Deployment action 4.2(*) Implement automatic speech recognition (ASR), user profile management system (UPMS) and attention guidance (AG) to provide a higher automation environment to support the ATCO role.	

* No ICAO Element yet – may be included in the next version of the GANP.

SDO 5: Transformation to trajectory-based operations (TBO)	**ICAO ASBU Element**
Deployment action 5.1 Implement enhanced conflict detection and resolution (CD&R) support tools by using aircraft-derived data (i.e. extended projected profile (EPP)) supported by the full implementation of aeronautical telecommunications network (ATS-B2) and high-resolution wind models.	FRTO-B1/5 FRTO-B2/4
Deployment action 5.2 Implement multi-element clearances using controller pilot data link communications (CPDLC) with lateral and vertical data link clearances and increased ground automation tools (e.g. CD&R tools) and trajectory prediction supporting the earlier detection and resolution of potential conflicts.	FRTO-B1/5 COM-B3/1
Deployment action 5.3 Implement a dynamic route availability document (RAD) to allow the dynamic management of restrictions based on traffic evolutions, better integration of letters of agreement (LoAs) between ATC centres and NM, and the provision of preliminary flight plans by airspace users. This will feed dynamic network constraints publications initiated the day before operations, to optimise the environmental performance of the network.	
Deployment action 5.4 Implement airspace user capabilities to provide, through the user-driven prioritisation process (UDPP), their preferences and priorities, and influence ATFM arrival regulations.	NOPS-B2/4
Deployment action 5.5 Implement interaction tools supporting the full integration of the flight operations centre (FOC) into the ATM network process and the flight delay criticality concept, to better integrate airspace user priorities in flow management decisions.	NOPS-B2/4
Deployment action 5.6 Exploit new FF-ICE/R1 trajectory services beyond the CP1 services (which are just the filing and trial services) to improve the completeness and accuracy of traffic load calculation and advanced network performance capabilities.	FICE-B2/1 FRTO-B2/4
Deployment action 5.7 Implement seamless ATC–ATC coordination and sharing with NM of the ATC–ATC exchanges, encompassing more complex coordination dialogues, implying negotiation between controllers across ACC boundaries. (Note the SESAR Deployment Manager’s action to build consensus on ATC/ATC TBO interoperability is ongoing).	FICE-B3/1

SDO 6: Virtualisation of operations	**ICAO ASBU Element**
Deployment action 6.1(*) Implement virtual centres to enable decoupling of the ATM data service provider (ADSP) and ATSU through service interfaces that support new ways of dynamic ATS delegation (e.g. contingency delegation, night delegation (scheduled), fixed time delegation (scheduled), 'on demand').	
Deployment action 6.2 Implement multiple remote tower module (MRTM) flexible and dynamic allocation of different MRTMs accommodated within a remote tower centre (RTC) that allows the ATCO to maintain situational awareness for two or more small airports. It includes the implementation of a low-cost surveillance service for supporting remote tower operations.	DATS-B1/1
SDO 7: Transition towards high performance of air–ground connectivity (multilink)	
Deployment action 7.1 Implement future air–ground communications network infrastructure, which supports multilink capability and complete mobility between different data links.	COMS-B2/1 COMS-B2/2 COMI-B2/3
Deployment action 7.2 Implement satellite communications (SatCom) class B, which enables data and voice communication services using existing satellite technology systems in oceanic, remote, polar and gradually continental airspace.	COMI-B1/3
Deployment action 7.3 Implement VDL2-M2 successor (e.g. terrestrial data link system L-band-digital aeronautical communication system (LDACS), data link for ATM and AOC operations over commercial communication systems (hyper-connected ATM) and satellite communications for both the continental and remote/oceanic regions).	COMI-B2/3 COMI-B3/2 COMI-B3/3 COMI-B3/4

* No ICAO Element yet – will be in next version of the GANP.

SDO 8: Service-oriented delivery model (data-driven and cloud-based)	**ICAO ASBU Element**
Deployment action 8.1 Implement a new service-oriented delivery model (data-driven and cloud-based) covering all phases of flight and enabling: • open ATM patterns enabling integration of components provided by various system providers to facilitate multi-vendor solutions using open platforms and interfaces; • decoupling of service and infrastructure layers through cloud computing (including the various system components); • a cloud-native architecture of components with standardised and open interfaces that can be deployed on commodity cloud technologies.	DAIM-B2/1 DAIM-B2/2 DAIM-B2/5 SWIM-B2/1 SWIM-B2/2
SDO 9: CNS optimisation, modernisation and resilience	
Deployment action 9.1 Implement a secured surveillance functionality that enables detection and, when possible, mitigation of security threats that could affect the surveillance chain.	ASUR-B4/1
Deployment action 9.2 Implement minimum operational network (MON).	NAVS-B0/4
Deployment action 9.3 Rationalise instrument landing system (ILS) and implement efficiency measures/methods for more cost-effective maintenance of ILS, providing a link between ICAO Doc. 8071 and national CNS provision.	
Deployment action 9.4 Optimise surveillance, leveraging terrestrial and space-based information.	

SDO 10: Enable innovative air mobility (IAM) and drone operations	ICAO ASBU Element
Deployment action 10.1 Implement system support and procedures to integrate instrument flight rules (IFR) RPAS and IAM in airspaces A to C, which are required to have detect and avoid (DAA) systems that perform at least as well as TCAS II (traffic alert and collision avoidance system II) and see and avoid.	ACAS-B2/2 CSEP-B3/2 FICE-B2/8
Deployment action 10.2(*) Implement foundational (U1) and initial (U2) U-space services as established by the regulatory framework for U-space (Commission Implementing Regulation (EU) 2021/664).	
Deployment action 10.3 Implement a common ATM-U-space interface and dynamic airspace reconfiguration service to help ATC actors in charge of airspace reconfigurations to increase safety, keeping crewed and uncrewed aircraft segregated within the designated U-space airspace.	NOPS-B2/7
Deployment action 10.4 Implement simultaneous non-interfering (SNI) operations (e.g. parallel or convergent point-in-space (PinS) procedures) and capabilities (i.e. GNSS and the RNP navigation specification) allowing airspace users (e.g. rotorcraft and VTOL- capable aircraft) to operate to and from airports, vertiports and TMAs without conflicting with other traffic or requiring runway slots.	APTA-B0/6 APTA-B1/1 OPFL-B3/1

* No ICAO Element yet – will be in next version of the GANP.

TABLE 18: MAPPING TO GANP

A.9 Mapping strategic deployment objectives against essential operational changes, and development priorities against SRIA flagships

This appendix maps the new essential operational changes (EOC) against the scope of the strategic development objectives (SDOs) and those essential operational changes previously defined in the 2020 edition of the European ATM Master Plan (Table 19). It also includes a mapping between the development priorities (DP) and the flagships identified in the Strategic Research and Innovation Agenda (SRIA) ([71]) for the Digital European Sky and the multiannual work programme 2022–2031 of the SESAR 3 JU ([72]) (Table 20).

A.9.1 Mapping new essential operational changes against the 2020 edition of the Master Plan

SDO ID	New	Master Plan 2020 edition
SDO 1	Alerts for reduction of collision risks on taxiways and runways	• Airport and TMA performance
SDO 2	Optimising airport and TMA environmental footprint	• Airport and TMA performance • Interconnected ATM network
SDO 3	Dynamic airspace configuration	• Fully dynamic and optimised airspace
SDO 4	Increased automation support	• Fully dynamic and optimised airspace • Virtualisation of service provision
SDO 5	Transformation to trajectory-based operations (TBO)	• ATM interconnected network • Trajectory-based operations
SDO 6	Virtualisation of operations	• Virtualisation of service provision • Fully dynamic and optimised airspace
SDO 7	Transition towards high performance of air–ground connectivity (multilink)	• CNS infrastructure and services
SDO 8	Service-oriented delivery model (data-driven and cloud-based)	• Interconnected ATM network • Digital aeronautical information management and MET services
SDO 9	CNS optimisation, modernisation and resilience	• CNS infrastructure and services
SDO 10	Enable innovative air mobility (IAM) and drone operations	• CNS infrastructure and services • U-space services • Multimodal mobility and integration of all airspace users

TABLE 19: ESSENTIAL OPERATIONAL CHANGE MAPPING

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[71] SESAR 3 JU, Strategic Research and Innovation Agenda.

[72] SESAR 3 JU, SESAR 3 Joint Undertaking Multiannual Work Programme 2022–2031.

A.9.2 Mapping development priorities against SRIA flagships

Development priority ID	Development action name	SRIA flagship
	Industrial research	
IR-1	**Transformation to trajectory-based operations**	
IR-1-01	Integrated air–ground trajectory management based on ATS-B2, including the extension for lower airspace and airport surface.	• Air–ground integration and autonomy • Connected and automated ATM
IR-1-02	Development of FF-ICE, including FF-ICE pre-departure enhancement and FF-ICE/R2.	• Connected and automated ATM
IR-1-03	Advanced network trajectory synchronisation in the execution phase.	• Connected and automated ATM
IR-1-04	Connected and integrated flight management system (FMS), electronic flight bag (EFB) and flight operations centre (FOC) functionalities for trajectory optimisation.	• Air–ground integration and autonomy
IR-1-05	Dynamic route availability document (RAD) towards a RAD by exception environment.	• Connected and automated ATM
IR-2	**Transition towards high performance of air–ground connectivity (multilink)**	
IR-2-01	Complete development of successor of VHF data link mode 2 (VDL-M2) (L-band digital aeronautical communications system (LDACS), hyper-connected ATM, satellite communications (SatCom) class A), covering civil–military dual utilisation.	• Connected and automated ATM • Civil–military interoperability and coordination
IR-2-02	Aircraft as a sensor, including transmission of humidity information to ground.	• Air–ground integration and autonomy
IR-3	**Future en-route and TMA ground platforms**	
IR-3-01	Addresses next generation ATC platform fully leveraging aircraft capabilities. This includes supporting a data-sharing service delivery model, resilient integrated communication, navigation and surveillance (CNS)/Meteo (MET) as a service and traffic synchronisation, accommodating the specific needs of the military, innovative air mobility (IAM), higher airspace operations (HAO) and U-space, etc.	• Connected and automated ATM • Virtualisation and cyber-secure data sharing • AI for aviation
IR-3-02	Artificial intelligence (AI) capabilities enabling the next generation platforms.	• AI for aviation
IR-3-03	Cyber-resilience and cyber-security capabilities enabling the next generation platforms.	• Virtualisation and cyber-secure data sharing • Civil–military interoperability and coordination
IR-3-04	Separation management for high levels of automation.	• Connected and automated ATM

Development priority ID	Development action name	SRIA flagship
IR-3-05	Demand–capacity balancing (DCB) and airspace configuration concepts for high levels of automation.	● Capacity on-demand and dynamic airspace ● Civil–military interoperability and coordination
IR-3-06	Future human–machine teaming.	● Connected and automated ATM ● Capacity on-demand and dynamic airspace ● AI for aviation
IR-3-07	Ground capabilities for reducing the ATM environmental footprint. This includes climate-optimised trajectories covering non-CO2 effects (e.g. contrails), environmentally optimised climb and descent operations, advanced required navigation performance green approaches, dynamic allocation of arrival and departure routes considering noise and local air quality, green ATC capacity concept, flexible eco-friendly clearances, wake energy retrieval (WER), integration of sustainable aviation fuel (SAF) and zero-emissions aircraft and environmental performance dashboards.	● Connected and automated ATM ● Aviation green deal
IR-3-08	Geometric altimetry.	● Connected and automated ATM
IR-3-09	CNS capabilities to increase ATM system robustness (e.g. satellite-based multilateration (MLAT)).	● Connected and automated ATM
IR-4	**Future airport platform**	
IR-4-01	Addresses the next generation airport platform fully leveraging aircraft capabilities. This includes supporting the data-sharing service delivery model, interconnected with other airports and their third parties (e.g. ground handlers), ANSPs, NM and CNS/MET as a service. facilitating the accommodation of IAM, the interface with U-space, as well as specific needs from the military.	● Connected and automated ATM ● Virtualisation and cyber-secure data sharing
IR-4-02	AI capabilities enabling the next generation of airport platforms.	● AI for aviation
IR-4-03	Cyber-resilience and cybersecurity capabilities enabling the next generation of airport platforms.	● Virtualisation and cyber-secure data sharing ● Civil–military interoperability and coordination
IR-4-04	Airport solutions for reducing environmental impact of operations. This includes green-taxiing related concepts and environmental performance dashboards.	● Connected and automated ATM ● Aviation green deal

Development priority ID	Development action name	SRIA flagship
IR-4-05	Future human–machine teaming.	Connected and automated ATM Capacity on-demand and dynamic airspace AI for aviation
IR-4-06	Optimisation of runway throughput.	Connected and automated ATM
IR-4-07	Smart airports, airports as multimodal nodes and the passenger experience.	Multimodality and passenger experience
IR-5	**Autonomy and digital assistants for the flight deck**	
IR-5-01	Single-pilot operations (SiPO). This includes new sensors and aircraft architectures for the evolution towards SiPO/highly automated operations.	Air–ground integration and autonomy
IR-5-02	Increased automation assistance for the pilot for ATM tasks. This includes improved flight-deck human–machine interface (HMI) and procedures for CPDLC and voice less technology.	Air–ground integration and autonomy AI for aviation
IR-5-03	Highly automated ATM for all airspace users. This includes performance-based CNS enablers (assured navigation for robust ATM/CNS environment for all phases of flight, alternative position, navigation and timing (A-PNT), electronic conspicuity, sense and avoid, etc.), to facilitate the integration of advanced airborne automation and future ATC platforms, as well as accommodating IAM and interfacing with U-space.	Air–ground integration and autonomy
IR-5-04	Airborne capabilities for reducing ATM's environmental footprint. This includes wake energy retrieval (WER), energy-based operations andenvironment-driven trajectory optimisation.	Air–ground integration and autonomy Aviation green deal
IR-6	**U3 U-space advanced services, IAM and vertiports**	
IR-6-01	U3 U-space advanced services addressing aspects such as common altitude reference, collaborative interface with ATC, tactical conflict detection and resolution and fairness in strategic deconfliction.	U-space and urban air mobility
IR-6-02	CNS capabilities for U-space, which includes detect and avoid, collision avoidance for UAS, and the use of mobile networks by U-space (including performance-based communication and surveillance services using mobile network infrastructure).	U-space and urban air mobility

Development priority ID	Development action name	SRIA flagship
IR-6-03	Extending the U-space ecosystem. This includes the use of U-space services by commercial aircraft, general aviation, crewed VCA and the use of U-space services outside U-space airspace.	● U-space and urban air mobility
IR-6-04	Enabling IAM/VCA (crewed and uncrewed) operations, including in complex environments, congested areas and vertiports. This includes IAM operational procedures enabling access to all types of airspace and vertiports (both VMC and IMC) and IAM automation, including simplified vehicle operations, automatic take-off and landing (TOL), resilient navigation and energy management.	● U-space and urban air mobility
Exploratory research		
Applied research		
AR-1	Research to help shape the future regulatory framework for a Digital European Sky	● Connected and automated ATM ● AI for aviation
AR-2	Definition of advanced U4 U-space services	● U-space and urban air mobility
AR-3	Integration of the next generation aircraft for zero-/low-emission aviation	● Air–ground integration and autonomy ● Aviation green deal
Fundamental research		
FR-1	ATM impact on climate change	● Aviation green deal
FR-2	Digital flight rules	● Connected and automated ATM
FR-3	Investigate quantum sensing and computing applied to ATM	● Connected and automated ATM

TABLE 20: MAPPING DEVELOPMENT PRIORITY TO SRIA FLAGSHIPS

A.10 Abbreviations

Abbreviation	Full term
A/G	Air/Ground
ACARS	Aircraft communications addressing and reporting system
ACAS	Airborne collision avoidance system
ACAS Xa	ACAS extended area
ACAS Xu	ACAS experimental upgrade
ACC	Area control centre
ACDLS	ATS common data link services
ADS-B	Automatic Dependent surveillance – broadcast
ADS-B-SBA	ADS-B space-based augmentation
ADS-C	Automatic dependent surveillance – contract
ADSP	ATM data service provider
AG	Attention guidance
AGL	Airfield ground lighting
AI	Artificial intelligence
AIC	Aeronautical information circular
AIM	Aeronautical information management
AIP	Aeronautical information publication
AMAN	Arrivals management
ANS	Air navigation services
ANSP	Air navigation service provider
AOC	Airline operation communication
AOP	Airport operations plan
API	Application programming interface
APM	Approach path monitoring
A-PNT	Alternative positioning, navigation and timing
APP	Approach
ARES	Airspace reservation management
ASBU	Aviation system block upgrade
ASM	Airspace management
ASR	Automatic speech recognition
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
ATN	Aeronautical telecommunications network
ATS	Air traffic service
ATSEP	Air traffic safety electronics personnel (ATSEPs)
ATSU	Air traffic service unit
AU	Airspace user
BaaS	Backend as a service
B2B	Business to business
CAI	Continuity availability and integrity
CAPEX	Capital expenditure
CAT	Category
CATC	Conflicting ATC clearances
CD	Clearance delivery
CD&R	Conflict detection and resolution
CDM	Collaborative decision-making
CISP	Common information service providers
CMAC	Conformance monitoring alerts for controllers
CNS	Communication, navigation and surveillance

Abbreviation	Full term
CNS-PM	CNS Programme Manager
CP1	Common Project 1
CPDLC	Controller–pilot data link communications
CURA	Civil use of released and available airspace
DAA	Detect and avoid
DAC	Dynamic airspace configuration
DAP	Downlinked aircraft parameters
DCB	Demand capacity balancing
DDA	Detect and avoid
DES	Digital European Sky
DFMC	Dual-frequency multi-constellation
DFR	Digital flight rules
DMA	Dynamic mobile areas
DMAN	Departure manager
DME	Distance measuring equipment
D-NOTAM	Digital notice to airmen
DP	Development priority
DPI	Departure planning information
DSD	Digital Sky Demonstrator
EAER	European Aviation Environmental Report
EASA	European Union Aviation Safety Agency
ECAC	European Civil Aviation Conference
EDA	European Defence Agency
eDME	Enhanced distance measuring equipment
EFB	Electronic flight bag
ENV	Environment
EOC	Essential operational changes
EPAS	European plan for aviation safety
Eurocontrol	European Organisation for the Safety of Air Navigation
EPP	Extended projected profile
ER	Exploratory research
ER-ATC	En-route air traffic control
ETS	Emissions trading system
EU	Europe Union
EUROCAE	European Organisation for Civil Aviation Equipment
EVS	Enhanced vision system
eVTOL	Electric vertical take-off and landing
FCA	Flight centric ATC
FCI	Future communications infrastructure
FF-ICE	Flight and flow information for a collaborative environment
FMS	Flight management system
FOC	Flight operations centre
FPL	Flight plan
FRA	Free route airspace
GA	General aviation
GANP	Global air navigation plan
GBAS	Ground-based augmentation system
GBAS DF/MC	GBAS dual frequency/ Multi-constellation
GBAS-GAST SF/SC	GBAS GAST special authorisation/Special category
GBAS-GAST	GBAS approach service type
GNSS	Global navigation satellite system
HA	High altitude
HAO	Higher airspace operations
HAPS	High-altitude pseudo-satellites
HCATM	Hyper-connected air traffic management
HF	High frequency

Abbreviation	Full term
HMI	Human–machine interface
IA	Intelligent automation
IaaS	Infrastructure as a service
IAM	Innovative air mobility
ICAO	International Civil Aviation Organisation
IFR	Instrument flight rules
IGS-to-SRAP	Increased glide slope to a second runway aiming point
ILS	Instrument landing system
IMC	Instrument meteorological conditions
iOAT FPL	Improved operational air traffic flight plan
IPS	Internet protocol suite
IR	Implementing rule
ISGS	Increased second glide slope
IT	Information technology
JU	Joint Undertaking
KPA	Key performance areas
LDACS	L-band digital aeronautical communication system
LEO	Low earth orbit satellites
LoAs	Letters of agreement
LTAG	Long-term aspirational goal
LPV	Localiser performance with vertical guidance
LVC	Low visibility conditions
MET	Meteorology
MFF	Multiannual financial framework
MIL	Military
ML	Machine learning
MLAT	Multilateration
MON	Minimum operational network
MP	Master Plan
MRTM	Multiple remote tower module

Abbreviation	Full term
MSAW	Minimum safe altitude warning
NAV	Navigation
NDB	Non-directional beacon
NM	Network Manager
NOP	Network operations plan
NOTAM	Notice to airmen
OP	Operation
OPMET	Operational meteorological information
OSI	Open systems interconnection
PaaS	Platform as a service
PANS-ATM	Procedures for air navigation services – Air traffic management
PANS-OPS	Procedures for air navigation services – Aircraft operations
PBCS	Performance-based communication and surveillance
PBN	Performance-based navigation
PENS	Pan-European network service
PinS	Point-in-space
PKI	Public key infrastructure
PUE	Power usage effectiveness
R&D	Research and development
R&I	Research and innovation
RAD	Route availability document
RFI	Radio frequency interface
RNP	Required navigation performance
ROT	Runway occupancy time
RP4	Reference period 4
RPAS	Remotely piloted aircraft systems
RPAS C2	RPAS command and control

Abbreviation	Full term
RSP	Runway surveillance performance
RTC	Remote tower centre
SaaS	Software as a service
SAF	Sustainable aviation fuel
SAT	Satellite
SatCom	Satellite communications
SATVOICE	Satellite voice communications
SBAS	Satellite-based augmentation system
SBAS DF/MC	SBAS dual frequency/ Multi-constellation
SB-S	Secure broadband – satellite
SDO	Strategic deployment objective
SECRAM	Security risk assessment methodology
SES	Single European Sky
SESAR	Single European Sky ATM Research
SESAR DM	SESAR Deployment Manager
SESAR 3 JU	SESAR 3 Joint Undertaking
SLA	Service level agreement
SNI	Simultaneous non-interfering
SiPO	Single pilot operations
SOA	Service-oriented architecture
SRAP	Second runway aiming point
SRIA	Strategic research and innovation agenda
SSA	Space situational awareness
SSR	Secondary surveillance radar
SST	Space surveillance and tracking
STAR	Standard terminal arrival
STCA	Short-term conflict alert
STK	Stakeholder
STM	Space traffic management
SVS	Synthetic vision system
SWIM	System-wide information management
TBO	Trajectory-based operations
TCAS	Traffic collision avoidance system
TCG	Technical coordination group
TMA	Terminal manoeuvring area
TRA	Temporary restricted areas
TRL	Technical readiness level
TSA	Temporary Segregated Area
TWR	Tower
UAM	Urban air mobility
UAS	Uncrewed aircraft system
UDPP	User-driven prioritisation process
UPMS	User profile Management system
USSP	U-space service providers
UTM	Uncrewed aircraft system traffic management
VCA	VTOL-capable aircraft
VDL	VHF digital link
VFR	Visual flight rules
VHF	Very high frequency
VOR	VHF omni-directional ranging
VoIP	Voice over Internet Protocol
VMC	Visual meteorological conditions
VPA	Vertical prohibited areas
VTOL	Vertical take-off and landing
WAM	Wide area multilateration
WER	Wake energy retrieval

TABLE 21: ABBREVIATIONS

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PDF 978-92-9216-214-6 doi: 10.2829/9855255 MG-01-24-000-EN-N