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European ATM MP Stakeholder consultation workshop pre-read material

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Abstract

This document constitutes a pre-read material for the European ATM MP Stakeholder consultation workshop that will be held on the 22nd and 23rd of April 2024 in Brussels. It provides a basis for an open discussion and collection of valuable insights from key stakeholders regarding emerging ideas for the Digital European Sky initiative. The information contained in the document should not be considered as final and only presents a picture of on-going progress in the campaign.

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1 The Vision

1.1 Digital European Sky: making Europe the most efficient and environmentally friendly sky to fly in the world

THE DIGITAL EUROPEAN SKY

In the future, all flights/missions (manned or unmanned) operate in a way that maximises, to the fullest extent, aircraft capabilities to reduce the overall environmental impact of aviation (CO2 and non-CO2). This applies from the ground to the higher airspace and comprises civil and military operations as well as innovative air mobility. The future ATM system is so precise that its optimisation takes into account the individual performance characteristics of each aircraft, user preferences, real time traffic and meteorological conditions throughout the network. This optimisation is systematic, continuous and extremely precise. It also provides even higher levels of safety, as potential conflicts between trajectories or traffic bottlenecks are resolved earlier than today. The passenger knows that when taking a flight his/her 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 the journey.

This transformation is possible thanks to the implementation of a new service delivery model (service oriented and cloud-based) in which service providers are able to dynamically and collaboratively scale up or down capacity in line with demand by all airspace users (both civil and military). Furthermore, civil-military collaboration has been fully developed and enables interoperability and secure data sharing. 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 flight/mission is the new norm thanks to high connectivity between the air and the ground. Each aircraft is continuously connected and sharing its trajectory with a highly automated traffic management system (one single trajectory reference shared across all involved actors on the ground and in the air). For most portions of flights, 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. Most routine tasks are managed through machine-to-machine applications. Large volumes of data flow in an effective and secured manner across trusted users.

Trust in the design and capability of the ATM system in Europe to harvest the full power of digital technologies to deliver higher levels of safety and reduce the environmental impact of aviation become so clear that all stakeholders at global level decide to adopt this model to foster the development of global air transport.

1.2 Performance ambition

1. As the challenge to achieve climate neutrality goes beyond CO_2, the future design of the system should be able to adapt, monitor and strike the right balance between minimising CO_2 emissions, while addressing non-CO_2 impacts, noise and local air quality.
2. Help transform the way airspace capacity is delivered enabling ATS providers to dynamically scale up or down airspace capacity in line with all demand (both civil and military, manned and unmanned). These capacity adjustments should be implementable within minutes and ensure an optimal and cost-effective use of resources at any moment (airspace, data, infrastructure and human/machine teaming).
3. Further increase safety levels to cope with increased traffic numbers and diversity.
4. Ensure that data flows freely across trusted users and in a secured manner.
5. Improve the overall passenger experience through an integrated multi-modal transportation system ensuring punctuality and seamless connectivity.
6. Explore the social and human dimensions of such changes to ensure social acceptability and cost-efficiency.

The ATM Master Plan Target Vision aims at paving the way to realising significant enhancements in ATM performance across Europe by setting Performance Ambitions. Even though it is hard to predict exactly how the Digital European Sky (DES) Vision will change daily operations, we can still describe the expected improvements to the system's overall performance.

Flight operations will place environmental considerations at the core of decision-making processes at every level. This commitment will manifest through the rigorous reduction of aviation emissions and environmental impacts globally and locally. To move European air traffic management operations towards climate neutrality, planning and implementation of environmentally optimised flight routes, minimising both CO_2 and non-CO_2 emissions (in particular reducing the climate impact of long-lived warming contrails at an acceptable additional cost in terms of fuel and CO_2), will become the norm. TMA and airport operations will balance noise and local air emissions against operational efficiency, striving to minimise the disturbance and health impact on surrounding populations and airport personnel.

All ATM Key Performance Areas (KPAs) are interrelated and could enable synergies, where two performance areas influence each other positively, reaching simultaneously unprecedented performance levels that would be unfeasible in an isolated manner, or trade-offs, where these magnitudes move towards their optimum in diverging directions. Naturally, not all performance areas can be optimised in the same region all at once as they are not independent: sometimes a performance area may deliver better results than ambitioned at the expense of other areas.

Figure 1: Performance framework

Despite the fact that environmental concerns are growing, safety remains the top priority. Even with higher automation levels enabling more complex traffic, safety ambition shall remain for Phase D: no increase in the annual number of ATM/ANS related accidents despite any growth in traffic numbers and diversity that the system could allocate, implying in practice that no negative impact is observed in current levels as a result of system growth. The safety ambition encompasses all the ATM/ANS operating environment and related accidents.

The level for the achievement of the above ambitions relies on the significant enhancement of the capacity, predictability, and punctuality key performance areas. The first shall provide the necessary network throughput to accommodate all the growth of traffic forecast for 2040 - including airports as connected elements - in a scalable manner that enables similar levels of quality of ATM service to be provided despite relatively sudden changes in the operational factors (capacity and demand). Successive SESAR waves have delivered significant benefits for enhanced en-route and airport capacity, while a stronger focus should be put on the TMA environment in order to maximise overall network performance. In terms of network operations, the shift shall move towards arrival punctuality, enabled by the evolution of performance ambitions in departure punctuality and trajectory and network predictability – to improve today's levels with traffic and complexity increases.

The cost efficiency of the ANS system relies both on human operator productivity and the technology cost. Higher levels of automation in ATM operations will impact the balance between these magnitudes, boosting the number of flights that can be managed by an Air Traffic Control Officer (ATCO) while adding new technological layers and components that will increase cost. The system will rely on automation and -both technical and operational- scalability to be operated in a cost-efficient manner that does not compromise safety, environment or the passenger experience, providing similar levels of quality of service.

These operational performance areas are intrinsically linked to the passenger experience – arriving on time at the destination, in a predictable manner through an integrated multi-modal transportation system, supporting punctuality and seamless connectivity. Having a dedicated ambition illustrates the shift towards a more passenger-centric, performance-driven approach that

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evolves from flight delay reduction to overall on-time performance, with a focus on enhancing arrival punctuality and minimising network reactionary delays through improvements unpredictability.

This vision relies on the availability and secured exchange of data/information/intelligence among stakeholders, enabling unprecedented levels of automation and operational complexity, and preventing critical security incidents that could disrupt the traffic.

Finally, the gradual integration of new users (drones and IAM), corresponding services and supporting infrastructure is a key consideration, aiming at their synchronised inclusion in the lives of EU citizens and in Member States, with seamless deployment to normal U-space / ATM interconnected operations without negative impacts on other ATM key performance areas.

1.3 Key transformation levers

The implementation of the Digital European Sky is enabled by 5 key transformation levers, as depicted in the diagram below and subsequent textual descriptions.

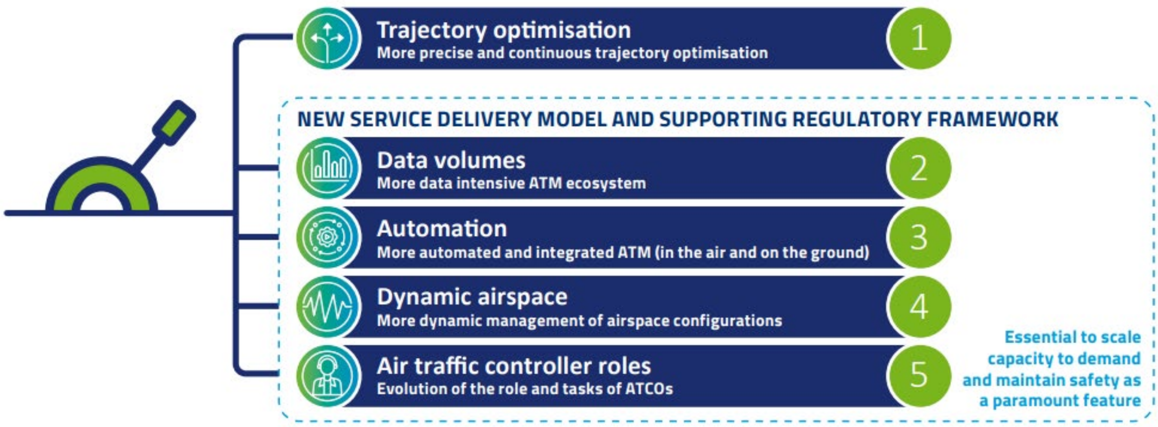

Figure 2: 5 Key Transformation Levers

1.3.1 Trajectory optimisation

Trajectory Based Operations (TBO) is an Air Traffic Management concept intended to enhance strategic planning of aircraft flows to reduce capacity-to-demand imbalance in the airspace System and provide tools to ATM personnel and controls to expedite aircraft movement between origin and destination airports.

TBO provides continuous and precise optimisation of trajectories in the vertical, longitudinal (speed) and horizontal dimensions in real time, bringing increased predictability, enabling a reduction in buffers and optimisation of capacity and resources.

TBO principles are applied in Air Traffic Flow Management (ATFM) and Air Traffic Control (ATC) operations, allowing collaborative decision making in planning, execution and post-operations in all ATM processes, from airspace management, ATFM and ATC.

Each aircraft is continuously connected and sharing its trajectory (one single trajectory reference shared across all involved actors) with a highly automated traffic management system on the ground and in the air enabling optimised flight planning and associated fuel upload.

By taking a holistic view of the trajectory from beginning to end, the TBO concept will enable airspace users to operate their preferred trajectory from gate to gate, in order to satisfy their business and operational needs, for example through 4D trajectory optimisation during the planning and execution phases.

The ultimate objective is precise management of individual trajectories resulting in optimising network performance through a gradual shift to trajectory-based operations, and capacity on demand leveraging on flow-centric concept and ATC complexity/workload balancing principles and digitalization such as ATM Data Service Providers and Virtual centres.

1.3.2 Data volumes

The move to SWIM and the introduction of TBO will result in a proliferation of data, including individual aircraft performance characteristics, user preferences, real time traffic and meteorological conditions throughout the network. This results in a more data intensive ATM eco-system in which real-time sharing of secured, trusted data is required amongst different stakeholders, including ANSPs, airspace users, airlines and airports. All airborne and ground systems and actors are interconnected and sharing the same distributed situation awareness.

The governance, security and confidentiality of sensitive information and data (including commercial information) used in aviation are crucial to ensuring the safe flight operations and to guaranteeing national security. The cybersecurity ecosystem is becoming more and more complex. Inevitably, threats are evolving in terms of both numbers and sophistication and as such, preventive and mitigative measures need to become equally more advanced.

Data flow and automation-centric governances

Data is a critical component in the development and deployment of AI applications, from a technical but also reliability perspective.

With the deployment of ATM Master Plan phases C and D, an ecosystem of aviation data flowing through fine-grained, cloud-based, and distributed services will increasingly become the heartbeat of European ATM.

Data Driven Architecture is an approach to building systems and applications that prioritises the use of data to inform design and decision-making. The goal of Data Driven Architecture is to create systems that are flexible, scalable, and responsive to changing data.

1.3.3 Dynamic Airspace

The concept of Dynamic Airspace is the ability to restructure airspace configuration and associated ATC utilisation in real time to respond to traffic demand and optimise use of human-automation teaming at network level enabling best use of advanced working methods based on higher levels of automation, resulting in a positive impact on the environment due to optimised flight trajectories, reduced flight time, less re-routes and level capping.

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Dynamic Airspace Configuration Objective

The objective of Dynamic Airspace Configuration (DAC) is to manage airspace in an efficient manner. Several concepts are expected to be developed to achieve the objective of Dynamic Airspace Configuration:

- Initial performance-based approach.
- Dynamic Sectors and Airspace Configurations based on Airspace Building Blocks and Controlling Building Blocks airspace design architecture.
- Non predefined Sector Configurations: fully dynamic Airspace Configurations are the means of integrated Demand Capacity Balancing process.
- Cross-border Airspace Configurations.
- Integration of Dynamic Mobile Areas (DMAs) of type 1 and type 2 into dynamic airspace configuration processes optimises the management of airspace and traffic flows.
- Move from collaborative processes to ASM merged with DCB into a fully integrated ASM/ATFCM/ATS CDM layered process.
- Dynamic Airspace Configuration through data uncertainty/confidence parameters, which are no longer bound to time parameters.
- Automation/system support for integrated airspace design, management and decision making.
- Data mining to feed automation.
- Enables User Preferred Route (UPR) operations.

In the transition period, with the conventional geographical sectors becoming more and more obsolete due to a higher level of automated support, the ATC tasks performed by humans will be very uniform, especially in less complex operations. This is a step forward to higher mobility of the ATCO workforce made possible by common licencing and rating requirements related to non-geographical but rather complexity-based ATC service provision approach.

The ultimate, most advanced option is non-geographical flight-centric (FCA) configuration of airspace as fully automatic ATC is not reliant on any sector boundaries.

1.3.4 Automation

To safely accommodate the increasing demand in traffic, airspace management will evolve towards progressively higher levels of automation, incorporating more digitised and automated services. AI-enabled systems shall process advanced climate and performance metrics.

By 2040 Human-Machine teaming will be enabled through a highly automated ATM system that adapts automation levels based on operational complexity, optimising performance at the same, or higher, level of safety.

To achieve this Vision, a few assumptions are considered:

a) Airborne Human-AI teaming: Reduced crew/single pilot managing the onboard automation and teaming with digital assistants.

b) Dynamic Airspace configuration and Management: The Airspace is designed and organized for dynamic management. Airspace organization and ATC constrains are adaptable in real time to respond to the traffic demand and the network performance enabling best use of advanced working methods based on higher level of automation.

c) Full connectivity: All airborne and ground systems and actors are interconnected and sharing same situation awareness.

d) EU ATM Data Ecosystem: System of accurate and consistent data for training of AI, with appropriate access rights (to guarantee business interests, e.g., ATC is allowed to access data of airline A, but airline B is not allowed to access data of airline A). Data is representative, AI is explainable and trustworthy.

e) Realtime data sharing: Amongst different stakeholders (ANSPs, aircraft, airlines, airports).

	Definition		PERCEPTION Information Acquisition & Exchange	ANALYSIS Information Analysis	DECISION Decision and Action Selection	EXECUTION Action Implemen-tation	Authority of the Human Operator
1A	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).	■	■		◢	full
1B	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).	■	■	▢	◢	full
2A	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 human **direction**.	■	■	◩	■	full
2B	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 the decisions that are not deemed appropriate. Automation acts under human **supervision**.	■	■	■	■	partial
3A	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**.	■	■	■	■	limited
3B	LEVEL 5 FULL AUTOMATION	**There is no human operator.** Automation acts without human supervision or safeguarding.	■	■	■	■	N/A

Table 1: Proposed new Levels of Automation Taxonomy and correspondence to EASA AI Levels

The decision-making is strongly supported by automation triggered by a capability to run big data (with the support of AI and machine learning), since the quantity of support data that could improve the decision making and the amount of time available for it, is beyond human ability.

Voice is currently the main pillar of air traffic management both for routine and urgent operations and tasks. The shift toward a mixed and complementary way for communicating based on both data and voice is a major evolution and needs to be gradual. Together with high connectivity between the air and the ground, this will support the setting of the right level of required performance, to find the right pace in deploying a performant future communication infrastructure, robust machine to machine applications for routine tasks, advanced avionics capability facilitating enhanced and efficient communication and collaboration between computers of different aviation stakeholders while rationalising the existing voice infrastructure (VHF minimum operating network).

1.3.5 Air Traffic Controller Roles

The introduction of new concepts and advanced technologies shall inevitably result in a change to the role of the Air Traffic Controller. Artificial Intelligence and Machine Learning shall accelerate the implementation of automation, especially for routine tasks. Working methods shall evolve towards greater collaboration between humans and machines. Current research is mainly developing solutions focusing on automation as a support to the human. In general, the automation should be developed to the extent that non-complex situations can be handled equal or better than when the human is involved, including full decision making and action implementation. European vision documents, such as the EASA AI Roadmap and Automation ATM Vision Roadmap, suggest achieving scalable capacity enabled by higher automation.

"Enable Human-Machine teaming through a highly automated ATM system that adapts automation levels based on operational complexity, optimising performance at the same (or higher) level of safety".

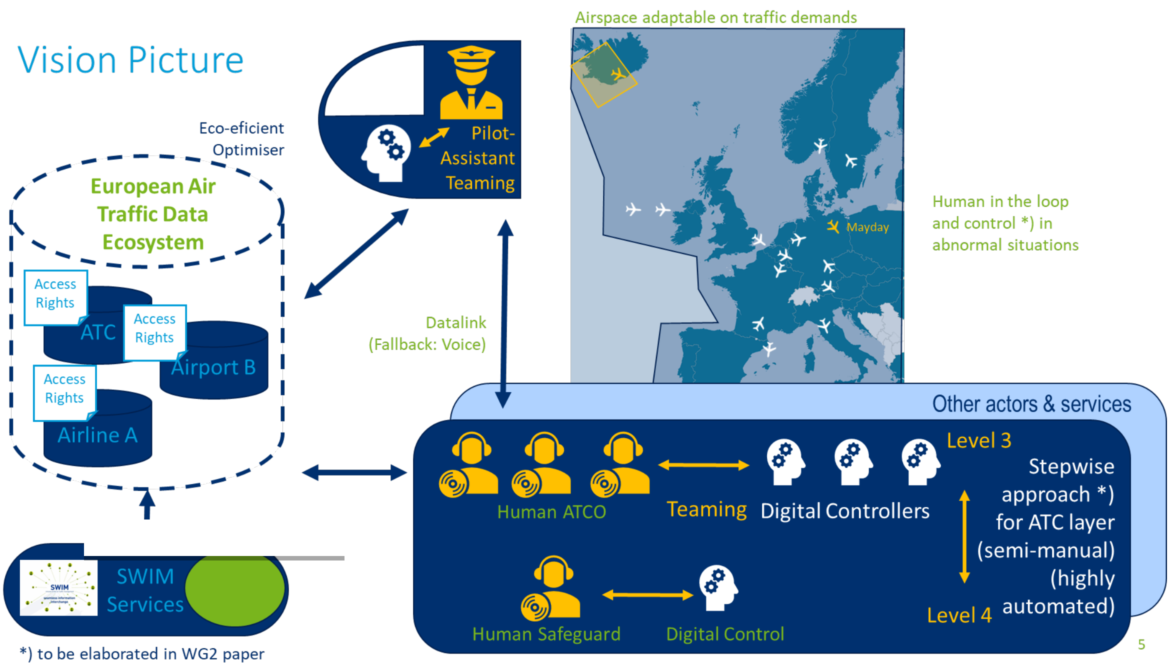

Figure : Human-machine teaming vision

The introduction of automation, enabled by AI and Machine Learning, shall see the role of the controller gradually morph across the following roles:

- Augmented controller: The human decides which tasks/situations are to be managed by the automation and by themselves, i.e. human air traffic controller to decide which aircraft should be guided by automation. The human controller oversees and can override the automation.

- Co-Worker: The human controller is responsible for separate tasks than the automation but might require collaboration on certain tasks, i.e. automated planner function suggests resolution of a conflict between two aircraft to the human executive air traffic controller.

- Supervisor: The human has a monitoring role and steps in once automation is unable to execute a task or a set of tasks, i.e. automation working out of its allocated operational design domain, based on an assessment by the automation itself or by a human supervisor. For example, automated air traffic control function is unable to handle a flight with a sick passenger on board resulting in a handover to a human air traffic controller.

The operating methods with higher levels automation shall rely on the intuitive design of the system to keep the human sufficiently in the loop.

To properly support the concept, the training methods need to be adapted to fit the new role of the operator. Research initiatives are needed to achieve the proposed levels of automation in Air Traffic Control - that will support transfer from single controller operations to automated operations with the controller in a monitoring supervisory role.

There may also be a need to address parts of the current ATM/ANS regulatory framework, such as the Air Traffic Controller Licensing and Certification regulation (EU) 2015/340 and the ATM/ANS regulation (EU) 2017/373.

Achieving a successful transformation for an optimised human-automation teaming within safety-critical environment needs a clear view on actual and future operational processes, involved social aspects and technical considerations to prevent potential loss of safety and reduced productivity during this transition phase.

The clear definition of the future Concept of Operations is essential for a safe human-machine teaming within an automated environment. Based on the identified and designed distribution of work, including actors, workflows and responsibilities, enabling a symbiosis between Human and Machines, bringing the ATM environment to a new level.

1.4 Target architecture and service delivery model

The purpose of the SESAR target architecture is to provide a blueprint to enable the modernisation of our infrastructure, systems, processes and operational procedures to enable an interoperable, modern and efficient digital European sky delivering environment-friendly, capacitive, and cost-efficient services to all airspace users.

2040+ Drivers

The drivers behind the definition of the target architecture are derived from the SESAR Vision and associated requirements are summarised below:

Sustainability

From a Target Architecture perspective, sustainability includes decarbonising[1] European ATM, CNS and IT ground infrastructure. The service orientation approach should enable the earlier reaping of operational benefits and payback, decrease time to operational deployment through the re-use of SWIM services, factor in security and infrastructure capabilities or improvements, and leverage the digitalisation of processes.

Inclusiveness for all stakeholders and modes of transport

The current ATM-centric architecture representation needs to evolve and become part of a wider multi-modal and holistic architecture. This requires in turn advanced automation and a strong service orientation to deliver U-space services (U3/U4) for the integration of certified UAS/RPAS in all classes of airspace and higher airspace operations. From the architecture perspective this implies that all stakeholders should contribute to the SESAR architecting activity.

Inclusiveness also applies for civil and military interoperability requirements, especially CNS. The target architecture considers civil-military requirements for CNS interoperability at the same level and as fundamental to ensure the required levels of connectivity and performance in a globally interoperable context, seamlessly accommodating safe and secure both civil and military operations.

Environmental footprint and seamless journey

Environmental data will help to inform better actions to reduce the overall aviation, and ultimately inter-transport, carbon footprint.

Dynamically and collaboratively scaling up or down capacity

The horizontal and vertical scaling capability could happen at organisational level through the virtual centres, and at infrastructure level with services deployed as independently as possible and hosted in clouds themselves to be scaled up and down.

A single trajectory reference

A single trajectory reference shared across all involved actors on the ground and in the air implies for all stakeholders to gradually move to a data driven architecture context and taking account of trajectory information synchronisation requirements stemming from trajectory-based operations (including trajectory consistency maintenance and equitable trajectory data access). As part of the governance, security and confidentiality of sensitive information and data (including commercial information) should be ensured.

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[1] Please note that sustainability refers to CNS, cloud services and ground equipment - environmental footprint of the ATM system not the aircraft footprint, therefore noise and local air quality are not mentioned here.

A systematic and continuous optimisation

The optimisation of operations will rely on network-wide dynamic airspace management, a gradual shift to trajectory-based operations, and provision of on demand capacity leveraging flow-centric concepts and ATC complexity/workload balancing principles and digitalisation such as ATM Data Service Providers and Virtual centres.

New service delivery models

A service delivery model specifies the stakeholders' organisational arrangements, roles, processes, and responsibilities in service provisioning. The challenge lies with analysing whether and how the different business capabilities and responsibilities can be shared, split, delegated, or transferred amongst business actors, in line with their business strategies.

Machine to machine applications for routine tasks

Voice is currently the main pillar of air traffic management both for routine and urgent operations and tasks. The shift toward a mixed and complementary way for communicating based on both data and voice is a major evolution and needs to be gradual. Together with high connectivity between the air and the ground, this will support the setting of the right level of required performance, to find the right pace in deploying a performant future communication infrastructure, robust machine to machine applications for routine tasks and advanced avionics capability while rationalising the existing voice infrastructure (VHF minimum operating network).

Highly integrated Infrastructure

The CNS services will be European-wide and globally harmonised, interoperable and specified through contractual customers and providers relationships with clearly defined level of quality.

The progressive introduction of a CNS service-based approach will enable the virtualisation of ATM (decoupling the provision of ATM data services from ATS) and will enable ANSPs to decide on how to provide the new services.

Architecture Steering principles

A Steering Principle is high level guidance to ensure that the Solution development and validation are consistent and coherent with the objectives set by the SESAR ATM Master plan vision.

Open and modular architecture

The Digital European Sky calls for an open, modular, service-oriented architecture consisting of self-contained functionalities with standardised interfaces, which expedite and ease the adding, upgrading, or swapping of functionalities throughout the system lifetime.

The current ATM architecture still relies mostly on large monolithic systems and products. Within the ATM systems, internal interfaces between functions resort generally to proprietary middleware, creating a costly technical and architectural debt to unlock the data. While the use of standardised and open SWIM services between organisations starts to expand to achieve compliance with IR CP1, most data flows still rely on point-to-point communications and ad hoc protocols. Besides, this first shift to SWIM does not solve the locking of data at the level of the functions.

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The target architecture should be service based (service orientation as overall design principle) and rely on published or standardised interfaces to easily make changes on the architecture components during the lifetime of the whole services ecosystem.

European SWIM governance and registry ensures their discoverability, fitness for purpose and equal and fair conditions of access to trusted potential and actual consumers and providers.

Key missing services will be detected, incubated in SESAR, and follow a fast-track collaborative service development and deployment.

Resilience

The selected target architecture will address situations affecting capacity or continuity, through a quick recovery after local or major disruptions. This translates into business continuity, capability to decouple the service provision from geographic location, dynamic ATS delegation and contingency management, and in an increased resilience and robustness of the CNS and IT infrastructure through virtual centre, aeronautical spectrum efficiency and adequate protection, open standards, and transition to CNS Minimum Operating Networks in Europe.

Scalability and infrastructure decarbonization

Architecture designing and IT infrastructure rationalisation should aim at dramatic reduction of its environmental footprint, measured by its Power Usage Effectiveness (PUE). IT rationalisation happens with the shift to cloud-based certified services in the target vision, whereby ANSPs procure services from ADSPs operating fine grained SWIM services run as Software as a Service or on Platform as a Service cloud services. While this technology and related providers offer the opportunity to reduce the environmental footprint of the IT infrastructure, they are new actors bringing risks and liability issues in operations that need to be addressed through associated SLAs and terms and conditions.

Data flow and automation-centric governances

Data governance provisions should include:

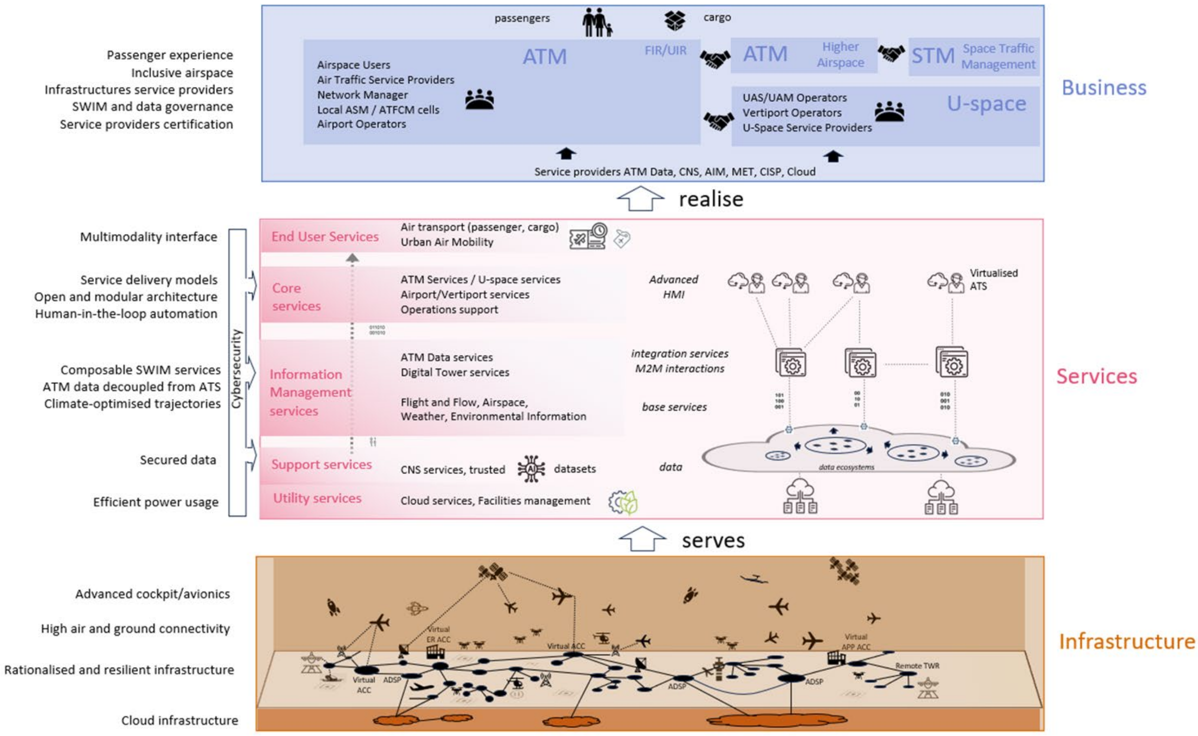
- Data flow-centric policies ensuring appropriate and commensurate attention to retrieve, access, use, process and deliver data in the cascading chain of actors.
- Automation-centric policies to ensure quality assurance, labelling, diversity, and representativeness of data, since automation must rely on unbiased datasets to the largest extent possible.

A supportive regulatory framework

The certification framework will need to evolve to allow for an accelerated transformation while maintaining necessary safeguards. In the target architecture, fine-grained, cloud-based & distributed services will be bundled to deliver the service that was operated through a system in the past.

The certification regime will need to factor in the even finer granularity of ATM and CNS services and their decoupling as the region gets closer to the target vision. In the same logic, as services shift to the cloud, there will be a need to decouple software certification from hardware certification (including the underlying infrastructure such as power, cooling system etc), especially in the case of specialised services (triangle architecture).

As the same performance-based logic percolates through all layers of the architecture, the certification regime will need to rely even more on performance driven provisions to accompany the building of an integrated, service-based, and robust CNS (using performance standards such as PBCS, MASPS and MOPS), without being overly prescriptive.



SESAR Architecture Overview

1.5 Enabling new forms of mobility and use of the sky

In 2040, the European airspace will be a hub for sustainable and innovative air mobility, where drone operations are seamlessly integrated, safe, and efficient. Drone operations safely rely on a resilient, digital infrastructure, supporting market growth in fair competition. The vision is driven by the evolution of U-space 2.0, a comprehensive framework that fosters fair competition, embraces automation, and ensures the secure and sustainable growth of the aviation industry. This will also facilitate a seamless integration of IAM, representing safe, secure, and sustainable air mobility in and outside urban environments (UAM), initially through crewed eVTOL operations, into the new multimodal transportation system.

U-space, as defined in 2016, is evolving into U-space 2.0 to accommodate the increasing complexity and demand for drone operations. The evolution aims to enhance existing services and procedures, while also introducing new ones to accommodate both crewed and uncrewed aircraft, leading to the convergence of ATM and UTM through open and standardised digital infrastructure. This development is informed by the experience and data gathered from the increasing number of flights. Automation levels will rise, supervised autonomous operations will be common, and a risk and performance-based approach will simplify complexity and lower entry barriers. U-space 2.0 allows better utilisation of already available digital information as well as existing infrastructure.

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Competent authorities, utilising available data, will ensure the safe operation of autonomous systems, fair access to airspace, and adherence to performance standards. This approach guarantees a reliable and socially accepted air mobility environment.

U-space development is being driven by new operations enabled by new vehicles. U-space 2.0 is an opportunity to make the traffic management as modern and performant as these vehicles and will harness enhanced computing capabilities and Artificial Intelligence (AI) for the rapid exchange, processing, and analysis of diverse data. This will enable precise control of high-density aircraft operations, accommodating the introduction of a more advanced digital flight technologies and capabilities into European airspace.

Digital traffic management services are designed to manage increasingly autonomous operations safely, economically, and efficiently through the provision of digital capabilities and services involving both airborne and ground-based functions.

The U-space infrastructure will evolve to seamlessly connect, and support crewed and uncrewed aircraft operations, vertiports, air traffic control, and airspace managers. As operations expand, the digital infrastructure will prioritise trust, cybersecurity, and scalability to accommodate future growth.

The U-space services are grouped in blocks of services known as U1, U2, U3 and U4.

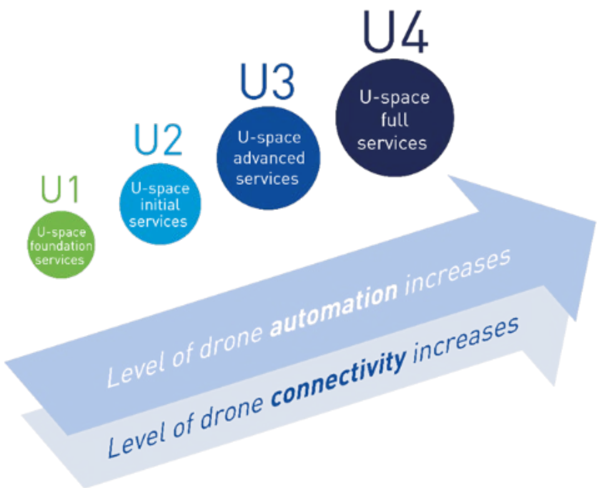

Figure 3 - U-space evolution

Since 2023, U1 is implemented, reflecting the obligations of the European regulation[2] - that there be a registry and that the geographic zones be publicly available.

U2 is in the implementation phase, driven by the regulatory framework[3] too. There are likely to be some minor refinements to the definitions of U2 services as they are deployed. This framework allows drone operations to take place in a segregated way from the other airspace users.

[2] EU IR 2019/947

[3] EU IR 2021/664 and others

U3 and U4 are currently under development and will enable higher density operations by means of tactical services including tactical conflict resolution, dynamic capacity management, a common altitude reference, as well as integration of the vertiport into U-space. More finely grained services will appear to allow further integration and inclusion of the Innovative Air Mobility (IAM) by 2040.

As Urban Air Mobility (UAM), a subset of IAM, will operate in and outside urban environments, U-space vision 2.0 aims to include IAM by extending beyond segregated airspace, ensuring the smooth integration of specific vehicles like eVTOL with both crewed and uncrewed operations.

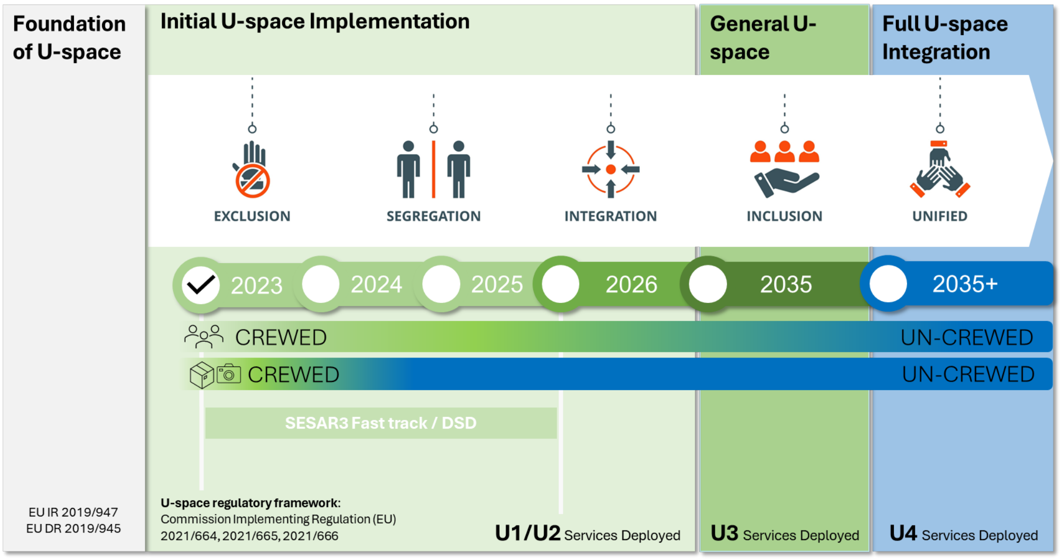

Figure 4 - Path toward an inclusive ATM

Inclusion of IAM into the overall air traffic ecosystem represents another important challenge for U-space vision 2.0. The first step being to extend beyond the boundaries of the U-space environment (segregated airspace) toward the integration of these operations that not only introduce specific vehicles, such as eVTOL, which require specific procedures for take-off/departure, approach/landing, and ground movements, but also typically necessitate access to multiple types of airspaces for both crewed and uncrewed operations.

By using U-space 2.0, other airspace users such as General Aviation (GA) and rotorcraft will obtain operational and safety benefits. U-space 2.0 facilitates interoperability between all the airspace users and will enable seamless information sharing between these different airspace users.

U-space 2.0 envisions that inclusion of IAM will be based on a well-balanced combination of conventional ATM and U-space services enabling smooth operations across diverse types of airspaces. Where needed (e.g. for vertiports located in an airport's area) this will be supported with specific IAM procedures, minimising impact on conventional air traffic operations (e.g. runway usage). The ATM and U-space services will complement and harmonise with advanced IAM functions which interface with either the vehicle or in the operator's ground systems such as ground control station. Scalable conflict management achievable through this approach will ensure safe and efficient IAM operations in mixed traffic environment with varying level of ground infrastructure, thereby enabling IAM business growth. The full deployment of U-space 2.0 and the diffusion of IAM operations in Europe will create a substantial economic impact and trigger transformation of various industries from a business perspective.

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U-space 2.0 outlines the objective of promoting the adoption of Innovative Air Mobility (IAM) by increasing the capacity for simultaneous operations and managing complex activities by 2040. This expansion necessitates enhanced coordination between Air Traffic Management (ATM) and U-space, requiring an evolution of both systems for successful U-space/IAM integration.

When the full U-space 2.0/IAM integration is completed, it is foreseen that both ecosystem, ATM and U-space 2.0, become one fully unified airspace ecosystem that allows all type of operations (crewed, uncrewed vehicles, and IAM), and ensures safety, economic sustainability, and environmental responsibility. Achieving this requires the exchange of best practices, synergies, and the incorporation of advanced technologies like cloud-based services and Artificial Intelligence to facilitate automation.

1.6 Enabling a secure European Sky and optimised enhanced civil-military coordination

Security context has drastically changed since 2020 due to the return of war in Europe. Russia's military aggression against Ukraine has resulted in the European Union taking action to support Ukraine and restore international legality. It is important to turn the EU's geopolitical awakening into a more permanent strategic attitude.

It is more urgent now than ever to strengthen the EU security and defence policy. It must be ensured that the additional investments are done in a collaborative way and that there are robust capabilities and the willingness to use them against the full spectrum of threats.

The capacity to tackle cyber threats, disinformation and foreign interference needs to be expanded in order to meet an ATM vision.

Cybersecurity vision for the years 2025 to 2030 is that the European Aviation ecosystem is **resilient** to cyber threats. It maintains its ability to always deliver the intended outcome continuously, even when regular delivery mechanisms are under cyber-attack. In the years 2030-2035 European aviation transitions from resilience to **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 but also evolve to anticipate and neutralise future cyber risks, thereby enhancing the overall security and reliability of European aviation. Civil - military aviation coordination and information sharing have significantly improved and responsibilities for the management of cybersecurity risks are appropriately assigned. From about 2040 on, the European Aviation cybersecurity reaches the **enlightened** state, 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, establishing an unparalleled level of proactive digital security.

The key to succeed in the future environment is to ensure that the upcoming European ATM ecosystem will have[4]:

- Fully integrated security and defence objectives together with economic, environmental and safety objectives.
- Fully developed civil-military collaboration, cooperation and coordination mechanisms and appropriate exploitation of synergies.
- Facilitated military Air Mobility.
- Achieved unconstrained military access to and seamless use of the airspace in particular for crewed and uncrewed future air combat systems.
- Guaranteed a secure and resilient CNS infrastructure, including a Minimum Operational Network, for civil and military assets. This in turn, will ensure fulfilment of the required level of performance and resilience and redundancy to ensure service continuity for state missions and international commitments.
- Enlarged the Recognised Air Picture to low level flights and HAO (Higher Airspace Operation) connected to Space Traffic Management, UTM, ATM and STM fully integrated in a seamless airspace.
- Made possible an interoperable and appropriately secure civil-military data and information exchange allowing to detect, identify and classify any cooperative and non-cooperative civil or military air system, and to intervene when needed.
- Achieved performance based and dual use benefits to the maximum extent possible considering military peculiarities from the outset.
- Optimised interoperability and synergies contributing to limit additional equipment requirements for military assets to operate in a modernised (civilian) ATM system.
- Guaranteed protection of availability, integrity and confidentiality of mission critical data supported by a resilient and robust civil and military data sharing network ensuring cyber resilience of this vital infrastructure.
- Adapted EU funding mechanisms will support EU aviation and defence industry competitiveness and will facilitate the development of dual use technologies.

[4] This encompasses many national prerogatives on which State will decide in terms of priorities.

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2 Roll-out

SESAR is a policy-driven innovation programme, supporting the EU Aviation Strategy and the implementation of the Single European Sky. Starting from the SESAR vision, the priorities for development and deployment are defined in this Master Plan. This chapter looks at the current state of implementation. It lays out what are the immediate next steps in deployment and in further development in order to reach the target vision. Finally, the context is provided from an EU policy perspective, as well as from the European and Global view.

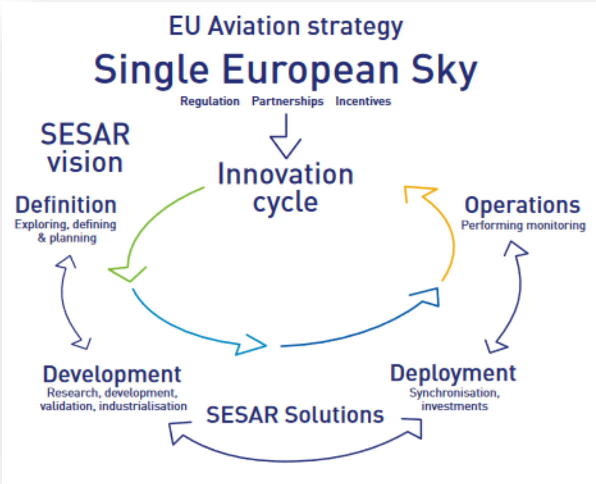
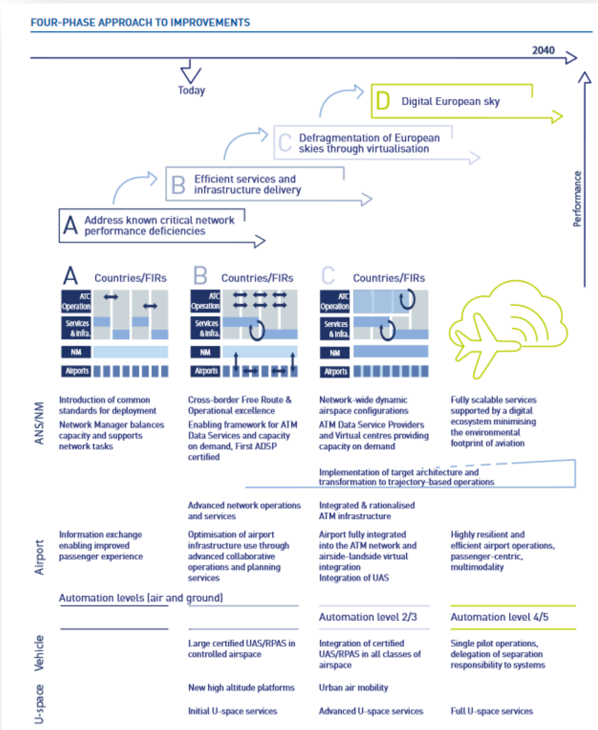


Figure 5 - SESAR Innovation cycle

2.1 Current state of implementation

SESAR has chosen a phased approach with four consecutive phases, overlapping in time:

- Phase A: addressing known critical network performance deficiencies;
- Phase B: efficient services – including initial U-space– and infrastructure delivery;
- Phase C: defragmentation through virtualisation and automation support, implementation of advanced U-space services;
- Phase D: full implementation of the Digital European sky, realising the target architecture of the Master Plan Vision.



At the time of this Master Plan edition, the Phases A and B are in deployment (through the support of CP1 regulation) with many benefits already realised for the European air traffic management system.

The R&I performed on Phase C has also delivered the technological and operational improvements that will provide further performance benefits through their deployment. These improvements have been prioritised, thus constituting the next wave of deployments. The Strategic Deployment Objectives shall deliver the full Phase C of the Vision by 2035/2040.

The Phase D will be delivered by the improvements that are currently in the R&I/development phase or entering the R&I phase in the coming years . These improvements are then going to be deployed in Europe by 2040.

2.2 Key milestones towards the target vision

2.2.1 Critical path for eliminating environmental inefficiencies

Aiming to implement the target vision, the critical path for eliminating environmental inefficiencies has been defined to reach the related target vision and architecture with a specific focus on safety and environmental sustainability fed by improved capacity, flight efficiency and predictability.

Improving ATM capacity and efficiency

The interdependency of the key performance areas is exemplified e.g. by the negative environmental impact caused by a lack of capacity and the obligation to use non-optimal routings. The goal is to move to a net-zero CO2 emission level by 2050, while accommodating the expected traffic growth to 16 million flights.[5] for Europe.

Facilitating and optimising the benefits from the use of SAF

A large part of reaching this goal will be realised by the introduction of new fuel, new engines and new aircraft technology. Battery-electric vehicles with no CO2 emissions can be used on shorter flights and in U-space operations. The advent of hydrogen-powered aircraft is announced for 2035. And the usage of sustainable aviation fuel (SAF) with a specific focus on e-fuels.[6] is regulated by the RefuelEU regulation. ATM will support the specific needs and flight profiles of new vehicles. In addition, ATM could play a role in the incentivisation of SAF uptake.

Non-CO2 impact of aviation

The deployment of any strategy for the mitigation of non-CO2 impacts based on the deviation of aircraft from their route will cause extra CO2 emissions, and hence it will require an agreement on an aggregated metric that considers CO2 and non-CO2 impacts. Any individual measure may be counterproductive, hence the need to develop a coordinated approach, especially when traffic

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[5] STATFOR forecast: ECAC area

[6] e-fuels: Power-to-fuel process, CO2-efficient with usage of renewable energy

demand is high. The type of fuel on-board, and more specifically the level of particulate matter and its corresponding contrail formation potential may also be considered as part of the strategy, for example by establishing an eco-measure for mandatory deviation affecting only certain types of fuel, or by prioritising aircraft with cleaner fuel in case of overdemand in a potentially eco-sensitive area. The availability of enhanced predictions of E-sensitive areas will require the deployment of humidity sensors in aircraft, the downlink of the data in real time and its processing by a MET service provider.

Improving flight efficiency by reducing fuel burn per flight

Like a bird, a moving aircraft leaves a wake of disturbed air, creating an updraft that allows a following aircraft to cut down on engine thrust, fuel use and emissions (around 5%). On the ground, engines-off Sustainable Taxiing through use of a Sustainable Taxiing Vehicle supports the use of airport-based specialised equipment to allow for sustainable taxi-out and taxi-in of aircraft. This allows for a safe, environmentally friendly and efficient ground operation.

Developing the environmental performance monitoring and management

The environmental inefficiencies influenceable by ATM will be tackled at all phases of flight. The goal of this Master Plan is to ensure that the increase in the efficiency of the ATM system outpaces the growth of traffic. To support the measurement of improvements, an evolution of the environmental performance monitoring and management is planned.

Improvement of local air quality and reduction of noise at airports.

PBN implementation – supported by the PBN regulation - has brought about more fuel-efficient RNP approaches to airports. In addition, the design of new approaches can avoid populated areas for less impact on noise and air quality. Another short/mid-term improvement is the use of increased glide slopes with a second runway aiming point, thus reducing noise. This also has a positive effect on runway throughput through wake vortex spreading.

In the longer-term (for Phase D), the improved air/ground connectivity will allow the exchange of more information with an impact on the combined optimisation of operation, e.g. through synchronised A/G speed and vertical flight path management on final approach, or dynamic allocation of optimised arrival and departure routes.

On the airspace management: dynamic RAD phase 1 and for the longer-term phase 2.

As mentioned above, the availability of the right capacity, predictability and flight efficiency is enabling the planning and use of environmentally optimal routes and thus reduce the environmental impact in the transition phase to new power concepts. The implementation of trajectory-based operations supported by high levels of digitalisation, automation and computer-aided decision support, improved A/G and G/G communication, dynamic shared network-based optimisation, will ultimately bring about environmental benefits besides the operational improvements.

While the environmentally optimal en-route flight path can be determined and flown today, supported by Free Route Airspace there are innovative concepts underway to reduce the fuel consumption today – and the flight energy consumption tomorrow: the in-trail (WER) operations of aircraft bring considerable savings.

2.2.2 Reaching the target architecture

Automation, machine-learning and the support of artificial intelligence (AI) in decision making are paving the way for the Digital European Sky. This enables progress from a local optimisation through advanced data sharing into a joint optimisation with a network perspective.

The Digital European Sky needs to be cyber-secured. Independent from the mode of the provision of services in localised, virtualised, network or distributed manner, the digital ecosystem needs to ensure that only authorised access can happen through authentication, and that external attacks can be compensated through cyber-hardened systems and a resilient response.

A key enabler is an efficient infrastructure for CNS to reach the target architecture, in which there is full integration – where required - of crewed and uncrewed air traffic and the seamless interaction between today's controlled airspace and the U-space.

In addition, the air traffic management system should allow full scalability, based on the planned demand of all actors. Thus accommodating the needs of the civil and military communities, with the highest level of co-operation to optimise the mutual efficiency.

The European target architecture is and will be operating in a global context. Therefore, the sharing of architectural concepts, the alignment between the GANP and the Master Plan, and the continuous ensuring of global interoperability is essential for its success.

The targeted European ATM vision should thus become a role model for the ATM worldwide.

2.3 Context around the roll out

The rollout of technical and operational improvements to reach the Master Plan target architecture and vision will be happening in a dynamically developing air traffic management system with a clear focus on improving performance. While safety is still the most important performance area for aviation, there is a focus on environmental sustainability and how to lower the impact of aviation on the environment. This is in line with having sufficient capacity, flight efficiency and predictability available, as a degrading of any of the latter would also have an impact on fuel burn and emissions.

The Master Plan implementation is happening in an overall EU regulatory framework, putting the emphasis on sustainability and being related to the European Green Deal. Linked to the goal of reducing net greenhouse gas emissions by at least 55% by 2030, are the EU Emissions Trading System (ETS) putting a price on carbon, and also the ReFuelEU Aviation Initiative which will oblige fuel suppliers to blend increasing levels of sustainable aviation fuels into jet fuel taken on-board at EU airports, including synthetic low carbon fuels, known as e-fuels.

At the same time, research is continuing on measuring the impact of non-CO2 emissions. The impact of contrails - and their avoidance - on the environment has to be gauged in order to minimise the environmental impact of aviation. In addition to the optimisation of flight trajectories, there will be disruptive solutions finding new fuel savings, similar to electric taxiing or in trail operations. The major aircraft manufacturers have furthermore announced the availability of zero-emission next generation aircraft by 2035. In the meantime, the research on accommodating electric and hydrogen-powered aircraft will continue.

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In the U-space the aerial vehicles shall all be zero-emissions from the start. Here the research will cover noise as an environmental impact. Moreover, the efficient implementation of Innovative Air Mobility (IAM) should be achieved. The level of services for U-space and air traffic management should be scalable and more predictable, fully supported by a digital ecosystem, in which the digitalisation, cybersecure data sharing, automation and AI-supported decision-making will bring about the digital European sky. This will be done for the benefit of the citizens in general and of passengers in particular. The passenger experience improvement, including multimodality induces research together with other modes of transport research programmes like rail. Joint research will target joint optimisation.

All of the above has to happen on one hand with continuously improving transversal civil-military co-operation, and on the other hand in a global context connecting to the ICAO GANP . The changing military requirements due to evolving threats and the introduction of new generation fighter systems, may require additional airspace and resources as compared to before. Similarly, the developments of new generations of drones and higher airspace operations (HAO) need to be accommodated. The latter may also be connected to other EU research clusters for satellites, space launches and operations, and defence.

3 Deployment priorities

Introduction

Strategic deployment objectives (SDOs) are prioritised actions to deploy operational/ technological improvements resulting from validated SESAR solutions (TRL 6 level) that are supporting the critical path to reach the ATM vision and associated steering performance ambitions.

There are two types of SDOs: voluntary SDOs and mandatory SDOs.

Voluntary SDOs are strategic deployment objectives that can be voluntarily adopted by stakeholders: early movers can take the decision to deploy one SDO. Voluntary SDOs do not constitute an obligation or commitment to deploy; they provide a strategic basis to support investment decisions by early movers and secure that related industrialization / regulatory activities are adequately foreseen (when appropriate).

Ten voluntary SDOs are identified:

- SDO#1 Alert for reduction of collision risks on taxiways and runways
- SDO#2 Optimising airport and TMA environmental footprint
- SDO#3 Dynamic airspace configuration
- SDO#4 Increased automation support for controllers
- SDO#5 Transformation to trajectory-based operations (TBO)
- SDO#6 Virtualization of operations
- SDO#7 Transition towards high level of air-ground connectivity (multilink)
- SDO#8 Service-oriented delivery model (data driven and cloud based)
- SDO#9 CNS rationalization and modernization
- SDO#10 Implement innovative air mobility (IAM)

Mandatory SDOs are strategic deployment objectives that constitute an obligation or commitment to deploy.

While there are already existing important Implementation regulations (such as IR PBN 2018-1048, IR Data link 29/2009…), the previous version of the European ATM Master Plan already identified Common Project 1, which in the updated Master Plan version constitutes a mandatory SDO:

- SDO#11 Common Project 1 Implementation

The following sections provides, for each SDO the strategic deployment objective overview and its implementation actions where ATM investments should be planned between 2025 and 2035 to put essential elements of Phase C into motion; each implementation action is characterised with stakeholder category (ANSPs, airport operators, airspace users, the Network Manager, USSP, CISP, Drone/UAS Operator, Vertiport and the military) and operating environments applicable per implementation action such as airport, TMA, En-Route and Network.

The industrialisation challenge reflects whether the implementation can proceed immediately or not based on the current regulatory framework.

The implementation timeframe reflects, per implementation action, when the implementation can actually start: either between 2024-2029, or later.

The voluntary strategic objectives are mapped to the Essential Operational Changes (EOCs) (see annex 11).

3.1 Strategic Deployment Objective (SDO)

3.1.1 SDO#1 Alert for reduction of collision risks on taxiways and runways

This strategic deployment objective aims at mitigating the safety issue assessed with an elevated priority index by EASA "Undetected occupied runway (SI-2006)", by an aircraft landing or taking-off on an already occupied runway.

The objective is to maintain or increase the level of airport safety with increasing traffic in all weather conditions and improve airport resilience. Better human performance and reduced stress workload and for ATCOs as well as for the flight crew and vehicle drivers thanks to an increased situational awareness and automated decision support.

SDO#1 Alert for reduction of collision risks on taxiways and runways					
Deployment actions		**STKs**	**OP. ENV.**	**Estimated Implementation Timeframe**	
ID	**Description**			**2025-2029**	**Beyond 2029**
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	TBC	
1.2	*Implementation of guidance assistance/taxiway centreline lights at the airport for controllers, flight crews and vehicle drivers providing an unambiguous route for the taxiing aircraft/vehicle to follow through airfield ground lighting (AGL). Taxiway centre line lights are automatically and progressively activated (switched on to green), either in segments of several lights or individually, along the route cleared by the controller.*	ANSP AO	Airport	TBC	
1.3	*Implementation of on-board systems to generate alerts when detecting risks of*	AU	Airport		

	collision with other traffic during runway and taxiway operations.	MIL			
1.4	*Implementation of Enhanced vision systems (EVS) and synthetic vision systems (SVS), alone or in combination, to enable more efficient taxi and landing operations in low visibility conditions (LVC).*	AU	Airport		

3.1.2 SDO#2 Optimising airport and TMA environmental footprint

The key objective of this strategic deployment objective is to reduce the noise impact at the airport and in its neighbouring area and improve fuel efficiency (and reduced CO_2 emissions). The reduced noise impact may lead to an increased airport slot allocation and/or a reduction of night curfew.

The primary benefits of an increase in the runway throughput (both for arrivals and departures) is the reduction of air transport delay or a potential increase of airport slot allocation at coordinated airports. Other benefits include improvements on predictability and resilience while maintaining or increasing safety. The implementation of dedicated ATC support tools will allow to mitigate the impact on ATCO workload and human performance.

Better situational awareness of the traffic situation at various airports with overlapping E-AMAN will improve the decision-making processes enabling a better use of available resources, reducing vectoring, holding and fuel consumption. A better integration of out-of-area inbound flights will relieve bunching, delays, and emissions.

Sharing departure planning information (DPIs) between regional airports and the network manager will improve predictability, air transport performance, and stability of the ATFCM process, leading to potential benefits on en-route capacity.

The SDO contributes to mitigate the safety issue assessed with an elevated priority index by EASA "Mass diversions (SI-2032)".

SDO#2 Optimising airport and TMA environmental footprint					
Deployment actions		**STKs**	**OP. ENV.**	**Estimated Implementation Timeframe**	
ID	**Description**			**2025-2029**	**Beyond 2029**
2.1	*Implementation of 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 AO NM MIL	Airport TMA En-Route NM		
2.2	*Implementation of solutions to better integrate large / very large airports*	ANSP AU	Airport	TBC	

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	and the network via enhanced AOPs-NOP tactical, pre-tactical and strategic planning and AOP to AOP collaborative planning process	AO NM	NM	
2.3	*Implementation of 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	TBC
2.4	*Implementation of 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.*	ANSP AU	Airport TMA En-Route NM	
2.5	*Implementation of 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 at reducing the aviation environmental impact (e.g., noise, fuel consumption, CO2 emissions, etc.) on the airport neighbouring communities*	ANSP AU AO MIL	Airport TMA En-Route	
2.6	*Implementation of 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.*	ANSP AU AO	Airport TMA	TBC

3.1.3 SDO#3 Dynamic airspace configuration

This strategic deployment objective aims at mitigating the safety issue assessed with an elevated priority index by EASA "Mass diversions (SI-2032)", regarding mass diversions due to airspace and/or airport closure, with a large amount of displaced traffic resulting in an overload for ATC and increase workload for the flight crew.

The objective is to support Airspace Users' optimised flight trajectories, reduced flight time and therefore reduce fuel burn and CO_2 emissions by enabling a better use of available ATC capacity and a better balancing of ATC workload, leading to reduced demand/capacity imbalances and an increase in ATCO productivity.

This leads also to a better trade-off between ATM performance and military operational requirements throughout more dynamic and integrated local ASM-ATFCM processes based on CDM.

SDO#3 Dynamic airspace configuration					
Deployment actions		**STKs**	**OP. ENV.**	**Estimated Implementation Timeframe**	
ID	**Description**			**2025-2029**	**Beyond 2029**
3.1	*Implementation of higher granularity and flexibility in the airspace configurations, dynamically adjusting them in response to changes on demand, and refining airspace management within and across ANSPs' areas of responsibilities*	ANSP AU MIL NM	En-Route Network	TBC	
3.2	*Implementation of 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 medium to short-term ATM planning phase supporting military airspace requirements*	ANSP AU NM MIL	En-Route Network	TBC	

3.1.4 SDO#4 Increased automation support for controllers

This strategic deployment objective aims at reducing ATC workload and increasing controller's efficiency (ATCO productivity) through higher levels of automation, while maintaining safety.

Enhanced sector team operations to optimise flight profiles, minimise delays and improve ANSP cost efficiencies, as well as the personalisation of working positions according to ATCOs' individual operational needs, requirements, and preferences, are constituent blocks of this strategic deployment objective, together with new HMI interaction modes.

SDO#4 Increased automation support for controllers					
Deployment actions		**STKs**	**OP. ENV.**	**Estimated Implementation Timeframe**	
ID	**Description**			**2025-2029**	**Beyond 2029**
4.1	*Implementation of higher granularity and flexibility in the airspace configurations, dynamically adjusting them in response to changes on demand, and refining airspace management within and across ANSPs' areas*	ANSP	En-Route		

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	of responsibilities				
4.2	*Implementation of automatic speech recognition (ASR), user profile management system (UPMS) and attention guidance (AG) to provide higher automation environment to support ATCOs role*	ANSP	TMA En-Route	TBC	

3.1.5 SDO#5 Transformation to trajectory-based operations (TBO)

Reduction of CO_2 emissions thanks to more efficient trajectories filed and flown by the airspace users. The opportunity to get the trajectory improvements already at flight plan level increases as well of predictability of the traffic. This is an essential element to ensure improvements of the capacity performance therefore a potential reduction of delays.

A better integration of airspace users (AUs) in ATM decision making process enables an optimal planning of ATM resources and provide more flexibility for AUs to reschedule their flights when facing capacity constraints and congestion. The reconciliation of AU driven prioritisation process with NM, Local DCB and Airport delivers significant AUs savings while enabling smoother and more predictable operations at network level. During disruptive conditions, the AUs could prioritise flights in accordance payload factor so making the air transport system more resilient to disruptions.

Better interactions and supporting processes through the different flight phases increases airspace users' flexibility to optimise their operational flight plan while better dealing with hotspots. ATM actors will be able to share dynamically an accurate picture of airspace users' preferences as well as network constraints and opportunities allowing optimised flight planning and flow management operations. Smoother control process, which improves the efficiency of air traffic control in Europe and make it possible to manage more flights with greater precision and punctuality, offering cost savings to airlines, reductions in CO_2 emissions and ultimately providing a better service for passengers.

Trajectory management improvements based on higher levels of automation in agreed trajectories exchanges (e.g., voice recognition, ground tools using big data analytics and machine learning) will be introduced to reduce trajectory uncertainty this consequently increasing capacity.

Improved predictability, vertical and horizontal flight efficiency, closer matching between flight profiles in the airborne and planning phases, and better use of capacity.

Increase in capacity (due to gains in terms of ATCO workload reduction and workload balance between ATCOs), operational efficiency and environment gains thanks to better flight profiles in climb and descent.

SDO#5 Transformation to trajectory-based operations (TBO)					
Deployment actions		STKs	OP. ENV.	Estimated Implementation Timeframe	
ID	Description			2025-2029	Beyond 2029
5.1	*Implementation of 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 ATN B2 and high-resolution wind models.*	ANSP AU	TMA En-Route		
5.2	*Implementation of 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 AU	TMA En-Route	TBC	
5.3	*Implementation of a dynamic Route Availability Document (RAD) to allow the dynamic management of restrictions based on traffic evolutions, a better integration of Letters of Agreement (LoAs) between ATC centres and the provision of preliminary flight plans by Airspace Users, ahead of dynamic network constraints publications initiated the day before operations.*	ANSP AU NM	TMA En-Route Network	TBC	
5.4	*Implementation of airspace user capabilities to provide, through the UDPP, their preferences and priorities and influence arrival ATFM arrival regulations.*	AU NM	Airport Network		
5.5	*Implementation of interaction tools supporting the full integration of the FOC into the ATM network process and the flight delay criticality concept, to better integrate airspace user priorities in flow management decisions looking at short term implementation step.*	ANSP AU NM	TMA En-Route Network		
5.6	*Exploitation of new FF-ICE/R1 trajectory services beyond the CP1 services, which are just the filing and trial services, for improving completeness and precision of traffic load*	ANSP AU AO	Airport TMA En-Route	TBC	

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	calculation and advanced network performance capabilities.	NM	Network	
5.7	*Implementation of seamless ATC-ATC coordination and sharing with NM of the ATC-ATC exchanges[7], encompassing more complex coordination dialogues implying negotiation between controllers across ACC boundaries.*	ANSP NM	TMA En-Route Network	TBC
5.8	*Implementation of data exchanges between Network Manager and all operational stakeholders to enable stakeholders that intend to implement new CDM processes in the planning and execution phase (FF-ICE R2) and update network trajectory with the best available data.*	ANSP AU NM	TMA En-Route Network	TBC

3.1.6 SDO#6 Virtualization of operations

This strategic deployment objective aims at mitigating the safety issue assessed with an elevated priority index by EASA "Mass diversions (SI-2032)", regarding mass diversions due to airspace and/or airport closure, with a large amount of displaced traffic resulting in an overload for ATC and increase workload for the flight crew.

The objective is to improve cost efficiency (with regards to remotely provided air traffic service for a single aerodrome or for multiple aerodromes with a fixed allocation) mainly through ATCO's/AFISO's productivity. Human performance and safety are maintained or improved thanks to adjusted procedures and/or new system functionalities.

A completely new way of ATS delegation (e.g., contingency delegation, night delegation) is enabled by the possibility to perform dynamic delegation of ATS via dynamic airspace configuration, specialised operational procedures, and resource management. ATS delegation enables more flexible ATC operations, leading to seamless, safe, secure, and cost-efficient services for airspace users, and overall improvement in the performance of air traffic service provision.

An improved flexible use of ATM Data Service Providers also allows operations in case of contingency and increase the resilience of ATM Service provision.

[7] Note that SDM action plan to build consensus on IOP is on-going

<table>
<tr><th colspan="6">SDO#6 Virtualization of operations</th></tr>
<tr><th colspan="2">Deployment actions</th><th rowspan="2">STKs</th><th rowspan="2">OP. ENV.</th><th colspan="2">Estimated Implementation Timeframe</th></tr>
<tr><th>ID</th><th>Description</th><th>2025-2029</th><th>Beyond 2029</th></tr>
<tr><td>6.1</td><td>Implementation of virtual centre to allow decoupling the ATM data service provider (ADSP) and air traffic service unit (ATSU) through service interfaces supporting new ways of dynamic ATS delegation (e.g., contingency delegation, night delegation (scheduled), fixed time delegation (scheduled), “on-demand”).</td><td>ANSP
MIL</td><td>TMA
En-Route</td><td colspan="2">TBC</td></tr>
<tr><td>6.2</td><td>Implementation of 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 2 or more small airports. It covers the implementation of low-cost surveillance service for supporting remote tower operations.</td><td>ANSP
AO
MIL</td><td>Airport</td><td colspan="2">TBC</td></tr>
</table>

3.1.7 SDO#7 Transition towards high level of air-ground connectivity (multilink)

This Strategic Deployment Objective aims at enhancing the efficiency and flexibility of the overall datalink system through the provision of resilient multilink and mobile communications capabilities to connect air and ground.

Datalink is a key enabler to increase aviation safety and capacity as well as support automation, efficiency, and scalability for airspace operations. Future communications infrastructure network infrastructure, which supports ATN/IPS multilink capability and complete mobility between different datalink, meeting civil-military interoperability requirements for ground/ground network interfaces, safety, and security requirements.

It represents a step for achieving the performance objectives for real-time sharing of 4D trajectories and timely access to ATM data and information services. It improves the cost of technology, the communications performance and security (resilience) while increasing the datalink availability and capacity.

SDO#7 Transition towards high level of air-ground connectivity (multilink)					
Deployment actions		**STKs**	**OP. ENV.**	**Estimated Implementation Timeframe**	
ID	**Description**			**2025-2029**	**Beyond 2029**
7.1	*Implementation of future ground communications network infrastructure, which supports ATN/IPS multilink capability and complete mobility between different datalinks.*	ANSP	Airport TMA En-Route Network	TBC	
7.2	*Implementation of SatCom class B, which makes feasible to provide data and voice communication services using existing satellite technology systems in oceanic, remote, polar, and gradually continental airspace.*	ANSP AU MIL	TMA En-Route	TBC	
7.3	*Implementation of VDL2 successor (e.g., Terrestrial datalink system L-band-digital aeronautical communication system (LDACS), datalink for ATM and AOC operations over commercial communication systems (Hyper connected ATM), Satellite communications for both the continental and remote/oceanic regions.*	ANSP AO AU MIL	Airport TMA En-Route Network	TBC	

3.1.8 SDO#8 Service-oriented delivery model (data driven and cloud based)

A service-oriented architecture is the foundation to enables this change in our today's System architecture and accelerate deployments and make a real difference to enable interoperability by decoupling services from the underlying infrastructure. Furthermore, the service-oriented delivery model will allow faster and iterative implementations of independent services, more cooperation, and a more competitive market as we lower market entry barriers.

The service orientation and cloud technology will not only reduce the cost of technology but also the costs of adding new functions or the integration of new automation tools. A robust data-sharing network with relevant cyber-protection and cyber-resilience is essential. Aeronautical information management (AIM) solutions will enhance the integration and brokering of data services. The timely and open standards based bi-directional information exchange will contribute to increase predictability, flexibility, and efficiency. Flight crews will benefit of enabled uplink information exchange in improving common situational awareness between flight crews and ground operations, while promoting more informed decision making. Ground-based systems and air traffic managers may benefit of downlink information exchange in obtaining near real-time information about surrounding airspace conditions (e.g., atmospheric conditions).

This strategic deployment objective aims to support the deployment of SWIM technical infrastructure enabling the ground/ground civil-military SWIM-based coordination. It is expected to strengthen security for all stakeholders.

SDO#8 Service-oriented delivery model (data driven and cloud based)					
Deployment actions		**STKs**	**OP. ENV.**	**Estimated Implementation Timeframe**	
ID	**Description**			**2025-2029**	**Beyond 2029**
8.1	*Implementation of Phase C target architecture and a service-oriented delivery model (data driven and cloud based).* *By 2035, a new core ATC service delivery model for operations in all phases of flight should be in place that enables:* • *Open ATM integration patterns enabling participation of third-party system providers.* • *Enables decoupling of service and infrastructure layers as defined in the Master Plan through Cloud Computing (including FDP, HMI and the relation between FDP and HMI).* • *New service agreements governing the delivery of core services (common to all ANSPs in Europe) vs additional services (specific to one ANSP).*	ANSP NM MIL	Airport TMA En-Route Network	TBC	

3.1.9 SDO#9 CNS rationalisation, modernisation and resilience

Cumulative cost efficiency benefits are expected to be realised through decommissioning overly redundant CNS infrastructure across the pan-European ATM network and reducing operating expenses to maintain legacy systems. CNS rationalisation, modernisation and resilience will lead to network optimisation, following the implementation of new functionalities and/or technologies to support high performance and efficiency (in terms of cost, spectrum, etc.). The service-oriented approach and the integrated CNS will foster this process. In addition, CNS rationalisation, modernisation and resilience will support the long-term availability of suitable radio spectrum and an improved environmental performance thanks to the reduction of excessive redundancy and removal of energy inefficient legacy systems. The potential for optimisation and rationalisation is recognised for the ground systems ILS, Mode A/C/S radars, etc.

These rationalisation, modernisation and resilience will be supported by the implementation of the minimum operational network (MON) and new and modern technologies more efficient in terms of spectrum and providing the required level of performance (e.g., ensuring resilience).

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New A-PNT solutions will improve resilience against jamming and especially spoofing attacks on GNSS. Advanced A-PNT solutions may also relieve spectrum required for new services.

Military infrastructure and systems will also contribute to CNS rationalisation, modernisation and resilience, leading to a more resilient and seamless European ATM network and introducing economies of scale. The civil-military cooperation and dual use of infrastructure will support a rationalised, modernised and resilient CNS infrastructure.

SDO#9 CNS rationalisation, modernisation and resilience					
Deployment actions		**STKs**	**OP. ENV.**	**Estimated Implementation Timeframe**	
ID	**Description**			**2025-2029**	**Beyond 2029**
9.1	*Implementation of GBAS based on single frequency signals to support Cat II/III precision approach, landing, and departure procedures in all-weather operations conditions.*	ANSP AU	Airport TMA	TBC	
9.2	*Implementation of A-PNT technologies based on L-DACS-NAV and enhanced DME.*	ANSP AU MIL	TMA En-Route	TBC	
9.3	*Implementation of data fusion for en-route and TMA surveillance chain integrating secured surveillance functionality enabling detection and when possible, mitigation of security threats that could affect the surveillance chain.*	ANSP	Airport TMA En-Route	TBC	
9.4[8]	*Implement minimum operational network (MON)*	ANSP NM	TMA En-Route Network		
9.5[9]	*Rationalise ILS and implementation of efficiency measures / methods for a more cost-effective maintenance of ILS, providing link between ICAO Doc. 8071 and national CNS provision.*	ANSP NM	Airport TMA Network		
9.6[10]	*Optimising surveillance*	ANSP	TMA En-		

[8] Linked to the "European CNS Evolution Plan" where implementation details will be developed.

[9] Linked to the "European CNS Evolution Plan" where implementation details will be developed.

[10] Linked to the "European CNS Evolution Plan" where implementation details will be developed.

		NM	Route Network		

3.1.10 SDO#10 Enable innovative air mobility (IAM) & drone operations

The objective of innovative air mobility (IAM) consists of the safe, secure and sustainable air mobility of passengers and cargo enabled by new-generation technologies integrated into a multimodal transportation system.

This strategic deployment objective covers areas such as the integration of IFR RPAS, U-space, the interface ATM and U-space and the integration of IAM users in airports and TMAs without interfering with other traffic.

Implementing IAM will not only allow airspace users to access the airspace and to use infrastructure and services in a safe and equitable manner. Key benefits will also cover capacity, allowing to accommodate several users, both inside and outside U-space airspaces, depending on the actual traffic conditions, weather situation, as well as CNS performances.

Interoperability will be improved by adhering to global standards and uniform principles, facilitating homogeneous and operational compatibility both at regional and global level.

This will lead to more operational and economic cost-effectiveness benefits for the different type of airspace users, gaining efficiency benefits in terms of fuel/energy consumption and noise reduction.

In this context, the ATM system will be more prone and flexible to accommodate changes in daily operations. This will be promoted by the introduction of novel safe and secure technologies and services, supported by the introduction of new operational procedures, which will increase the safety and reliability of the overall ATM system.

This SDO contributes to mitigate the safety issue assessed with an elevated priority index by EASA “Airborne conflict with an unmanned aircraft system (SI-2014)”.

SDO#10 Enable innovative air mobility (IAM) & drone operations					
Deployment actions		**STKs**	**OP. ENV.**	**Estimated Implementation Timeframe**	
ID	**Description**			**2025-2029**	**Beyond 2029**
10.1	*Implementation of system support and procedures for the integration of IFR RPAS and IAM in airspaces A to C are required to have Detect and Avoid (DAA) systems that perform at least as well as TCAS II (Traffic alert and Collision*	ANSP AU Drone/UAS Operator MIL	TMA En-Route	TBC	

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	Avoidance System) and See and Avoid			
10.2	*Implementation of foundational (U1) and initial (U2) U-space services as defined by the Regulatory Framework for the U-Space (Commission IR 2021/664).*	USSP CISP Drone/UAS Operator	TBD	
10.3	*Implementation of a common ATM-U-space interface and Dynamic airspace reconfiguration service to help ATC actors in charge of airspace reconfigurations to increase safety keeping manned and unmanned aircraft segregated within the designated U-space airspace.*	ANSP AU AO MIL USSP CISP Drone/UAS Operator	Airport Vertiport TMA En-Route	TBC
10.4	*Implementation of 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) allows IAM users (e.g., rotorcraft, eVTOL) to operate to and from airports and TMAs without conflicting with other traffic or requiring runway slots.*	ANSP AU AO	Airport TMA	TBC
10.5	*Implementation of ACAS Xa through a surveillance and tracking module (STM) which processes raw surveillance data coming from the surveillance sensors.*	AU MIL	TMA En-Route	TBC

3.1.11 SDO#11 Common Project 1 Implementation

This mandatory SDO covers the functionalities and sub-functionalities covered by the Common Project 1 (Commission IR 2021/116).

3.2 Conditions for successful deployment

The Strategic Deployment Objectives defined in section 5.1 shall contribute to accelerate the market uptake of the SESAR solutions by a critical mass of early movers (i.e. at least 20% of targeted investors willing to invest in the deployment of the SDOs and to complete the implementation by 2035). To secure a smooth implementation of the SDOs, the conditions for a successful market uptake are linked to:

- Standardization activities
- Regulatory activities
- Digital Sky Demonstrators

Regarding the standardisation activities required for the completion of the industrialisation phase, in order to ensure that the necessary standards linked to the deployment actions will be available in a timely manner, it will be essential to leverage the existing groups and mechanisms in place, since the readiness of the standards (and corresponding regulatory framework) is an element affecting the investors decision. The main objective of the European ATM Standards Coordination Groups is to coordinate the standardisation activities stemming from the European ATM Master Plan, in support of Single European Sky implementation. Therefore, the groups shall assess the standardisation needs arising from the different SDOs to consider their inclusion into the European Standardisation Rolling Development Plans, based on a prioritisation approach to be defined with the SESAR 3 JU. Once the needs will be identified and traced, the monitoring of the evolution of the standard development activities shall be done in close and timely coordination with the SESAR 3 JU TCG (Technical Coordination Group) which has the objective of de-risking the roll-out of the Strategic Deployment Objectives defined in the Master Plan (and facilitate accelerated SESAR market uptake).

Regarding the regulatory activities required for the completion of the industrialisation phase, it will be necessary that SESAR 3 JU and EASA will continue cooperating together to ensure that the strategic deployment priorities defined in the European ATM MP 2024 fulfil the required safety and regulatory criteria necessary for their inclusion into the are adequately supported by the EPAS Volume I 2026-2028 editions, in line with the EASA priorities. While remaining relevant to their respective scope.

Investors should take the opportunity provided by the SESAR 3 JU through the Digital Sky Demonstrator projects, to increase the maturity of solutions stemming from previous R&D phases, including the possible standard and regulatory gaps, and be able to foster the market uptake for the SDOs of their interest. Successfully deployment of SESAR Solutions could also be supported by funding mechanisms that should be made available in complement to Digital Sky Demonstrator (DSD) opportunities to support the uptake by the early movers.

In terms of investment timeframe, in order to put into motion the essential elements of Phase C it shall be necessary to secure the commitment from a critical mass of early movers (20% of the targeted investors) to start investing in the period 2025-2029 (i.e. in RP4) and to complete the implementation deployment by 2035.

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4 Development priorities

Introduction

Development priorities are ranked actions to develop research activities towards solution critical to achieve the vision and target architecture introduced in section 3.

There are two types of Development priorities: Industrial research and Exploratory research ones.

4.1 Industrial Research priorities

4.1.1 DP-IR#1 Transformation to Trajectory-Based Operations

- Description:

This development priority focuses on completing the industrial research needs that are identified in the TBO roadmap. This may include, pending finalization of the TBO roadmap, elements such as FF-ICE/R2 for the revision of the flight plan beyond the North Atlantic and intra-European use cases, AOC-EFB-FMS integration, etc.

- Link to the 5 key transformation levers.

Trajectory Optimization	Data volumes	Automation	Dynamic airspace	Air traffic controller roles
High	High	High	High	High

- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.1.2 DP-IR#2 Transition towards high level of air-ground connectivity (multilink)

- Description:

Complete R&D activities on the concept of “Hyperconnected ATM” - which explores the integration of non-safety, commercial links into a hybrid communication infrastructure for ATM safety communication needs - and the complete development on the new terrestrial link LDACS.

- Link to the 5 key transformation levers.

Trajectory Optimization	Data volumes	Automation	Dynamic airspace	Air traffic controller roles
High	High	High	High	High

- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.1.3 Future ATC platform for En-Route operations

- Description:

This development priority focuses on the evolution of the cruise phase of flight to an environment where ATC is fully automated and able to handle both nominal and non-nominal situations. The development of the future platform aims to incorporate advanced technologies and innovative approaches to implementation of a new service delivery model (service oriented and cloud based) in which service providers are able to dynamically and collaboratively scale up or down capacity in line with demand by all airspace users (both civil and military). Key areas of focus include bolstering cyber-resilience and cybersecurity to protect critical ATM infrastructure and data, harnessing artificial intelligence to optimise flight paths and airspace utilisation, and fostering enhanced civil-military collaboration for seamless airspace management.

- Link to the 5 key transformation levers.

Trajectory Optimization	Data volumes	Automation	Dynamic airspace	Air traffic controller roles
High	High	High	High	High

- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.1.4 Future ATC platform for TMA operations

- Description:

This development priority focuses on the evolution of the climb/descent phase of flight to an environment where ATC is highly automated (traffic is handled under closer supervision by air traffic controllers supported by digital assistants that are designed to safely handle a large number of routine tasks). The development of the future platform aims to incorporate advanced technologies and innovative approaches to implementation of a new service delivery model (service oriented and cloud based) in which service providers are able to dynamically and collaboratively scale up or down capacity in line with demand by all airspace users (both civil and military). Key areas of focus include bolstering cyber-resilience and cybersecurity to protect critical ATM infrastructure and data, harnessing artificial intelligence to optimize flight paths and airspace utilisation, and fostering enhanced civil-military collaboration for seamless airspace management.

- Link to the 5 key transformation levers.

Trajectory Optimisation	Data volumes	Automation	Dynamic airspace	Air traffic controller roles
High	High	High	High	High

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- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.1.5 Future ATC platform for Airport operations

- Description:

This development priority focuses on the evolution of the airside operations (incl. aircraft turnaround, taxi and take-off and landing clearances) in an environment where ATC is highly automated (traffic is handled under closer supervision by air traffic controllers supported by digital assistants that are designed to safely handle a large number of routine tasks). The development of the future platform aims to incorporate advanced technologies and innovative approaches to implementation of a new service delivery model (service oriented and cloud based) in which service providers are able to dynamically and collaboratively scale up or down capacity in line with demand by all airspace users (both civil and military). Key areas of focus include bolstering cyber-resilience and cybersecurity to protect critical ATM infrastructure and data, harnessing artificial intelligence to optimize taxiway routings.

- Link to the 5 key transformation levers.

Trajectory Optimisation	Data volumes	Automation	Dynamic airspace	Air traffic controller roles
High	High	High	High	High

- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.1.6 Infrastructure as a Data Service for Future Platforms (targeting CNS, MET, AIM & IT)

- Description:

This development priority focuses on the transition to Infrastructure as a Data Service to help feed future platforms, specifically targeting Communication, Navigation, and Surveillance (CNS), Meteorology (MET), and Aeronautical Information Management (AIM). It has to enable the transition to a new service delivery model (service oriented and cloud based) in which service providers are able to dynamically and collaboratively scale up or down capacity in line with demand by all airspace users (both civil and military).

- Link to the 5 key transformation levers.

Trajectory Optimisation	Data volumes	Automation	Dynamic airspace	Air traffic controller roles
High	High	High	Medium	Medium

- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.1.7 Enable Reduced/single Pilot Operation

- Description:

This development priority focuses on enabling Reduced/Single Pilot Operation (SPO) in the aviation industry. The transition to SPO is being investigated with a view to respecting societal expectations for a human presence in the cockpit, while leveraging increased automation for automatic flight phases. This involves the integration of AI and other advanced technologies to support human operators during complex scenarios, reduce workload, and ensure safety. The priority also emphasises the need for secure and efficient air-ground and air-air communication to support SPO and cross-border operations. Further, it explores the development of new human-machine interfaces and real-time workload monitoring systems based on AI. A key aspect of this initiative is the development of safety systems and crew health monitoring systems to ensure safe operations with a reduced crew.

- Link to the 5 key transformation levers.

Trajectory Optimization	Data volumes	Automation	Dynamic airspace	Air traffic controller roles
Low	Medium	High	Low	High

- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.1.8 Wake Energy Retrieval (WER) for Continental Airspace

- Description:

This development priority focuses on the application of Wake-Energy Retrieval (WER) in continental airspace. WER, inspired by the principle of migrating birds, involves aircraft flying in formation to achieve significant fuel savings. Formation flight tests have demonstrated potential fuel savings of between 5% and 10% per trip when two aircraft fly approximately 3 km apart, without compromising passenger comfort and safety. The priority involves research and innovation activities to develop the required avionics and necessary ATM procedures, with the aim to develop demonstrators and prepare for market uptake.

- Link to the 5 key transformation levers.

Trajectory Optimisation	Data volumes	Automation	Dynamic airspace	Air traffic controller roles
Medium	Low	Medium	Low	Medium

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- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.2 Exploratory Research priorities

4.2.1 DP-ER#1 Framework for AI trustworthiness applied to ATM

- Description:

This development priority aims at baselining how the four building blocks that are considered in the EASA AI Roadmap 2.0 as essential for creating a framework for AI trustworthiness focusing at Level 2 AI (human-AI teaming) and well as Level 3 (advanced automation). The four building blocks are: AI trustworthiness analysis, AI assurance concept, Human factors for AI and AI safety risk mitigation.

- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.2.2 DP-ER#2 ATM impact on Climate Change

- Description:

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 optimization strategies that can be automated and that consider the total impact on the climate of each flight. Accurate scientific data is necessary to develop evidence-based optimization algorithms and rules aimed at reducing the environmental impact of aviation. Without comprehensive research, it's challenging to implement measures that effectively balance e.g. the CO2 vs non-CO2 impacts.

- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.2.3 DP-ER#3 Digital Flight Rules

- Description:

This development priority focuses on the exploration and implementation of Digital Flight Rules (DFR), a proposed new set of flight rules that take advantage of the capabilities of on-board Detect and Avoid (DAA) capabilities to provide increased flexibility to the AU in a full electronic conspicuity environment. The ATM system that as a whole 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 e.g. PANS-OPS and PANS-ATM rules to allow leveraging technologies support an increase in safety, compatibility, operational efficiency, and international harmonization.

- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

4.2.4 DP-ER#4 Investigate Quantum Sensing & Computing Applied to ATM

- Description:

This development priority focuses on exploring the potential applications of quantum sensing and computing within the realm of Air Traffic Management (ATM). Quantum computing, a rapidly emerging technology, 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 research priority aims to position ATM to fully leverage the 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 effectively implement this technology.

- *Explanation of the link to the 9 flagships under SRIA and the 9 essential operational changes will be provided in draft v2.*

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The way forward

This European ATM MP Stakeholder consultation workshop pre-read material provides a baseline for an open discussion and collection of valuable insights from key stakeholders regarding emerging ideas for the Digital European Sky initiative and the continuous modernisation of ATM to be captured in the new edition of the ATM Master Plan.

The results of the April workshop as well as further contributions from the Working Groups will be used in the development of a mature draft update proposal of the European ATM Master Plan to be delivered end of May 2024 before finalisation of the work in July.