SESAR JOINT UNDERTAKING

SESAR 3 Joint Undertaking

MULTIANNUAL WORK PROGRAMME

2022-2031

EUROPEAN PARTNERSHIP

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ABSTRACT

This document is the draft Multiannual Work Programme document of the Single European Sky Air Traffic Management Research (SESAR) 3 Joint Undertaking (SESAR 3 JU) for 2021 to 2031.

It contains the core components of the work programme and the budget allocation principles for the SESAR 3 JU's activities over that period.

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1. INTRODUCTION

1.1. Objectives of the document

This Multiannual Work Programme establishes the framework under which the operations of the Single European Sky Air Traffic Management Research (SESAR) 3 Joint Undertaking (hereafter referred to the SESAR 3 JU) will be defined, planned and executed from 2021 to 2031.

It defines the overall life cycle of the SESAR 3 JU's research and innovation (R & I) programme (Digital European Sky Programme), which seeks to deliver the technological solutions needed to achieve the modernisation and digitalisation of air traffic management (ATM) in Europe, in line with the European ATM Master Plan ([1]). It also defines the activities of the SESAR 3 JU other than R & I, both operational and administrative.

Based on the SESAR 3 JU's basic act ([2]), this document lays down the following:

a) policy context,

b) strategic objectives,

c) Digital European Sky Programme activities,

d) other activities necessary to achieve the strategic objectives,

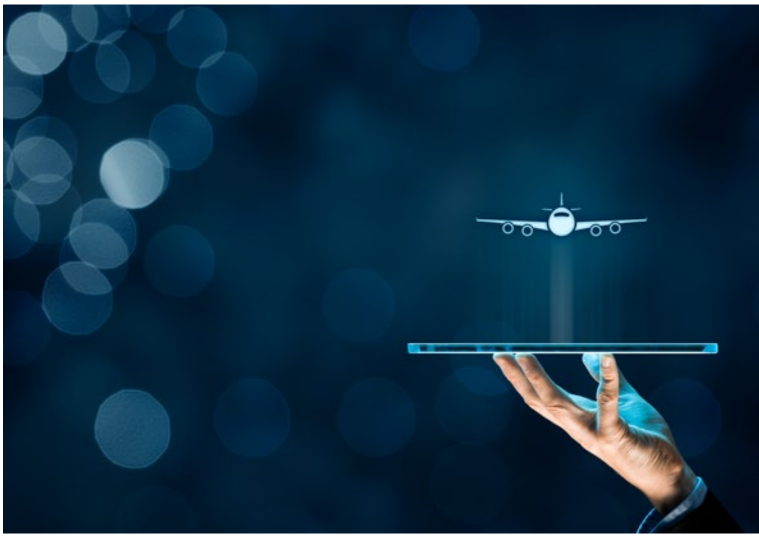
e) governance of the SESAR 3 JU and its R & I programmes.

Furthermore, to support the work programme elements, this document defines the main principles for the budget allocation from the overall SESAR 3 JU budget down to its operational and administrative components. Moreover, to secure the achievement of its strategic objectives, the management of its major risks and the sound management of its resources, both financial and human, the SESAR 3 JU will set up an internal control system, which is also defined in this document.

The present Multiannual Work Programme will be implemented through Bi-Annual Work Programmes developed by the SESAR 3 JU and adopted by the Governing Board.[3]

1.2. Background and policy context

1.2.1. The SESAR project



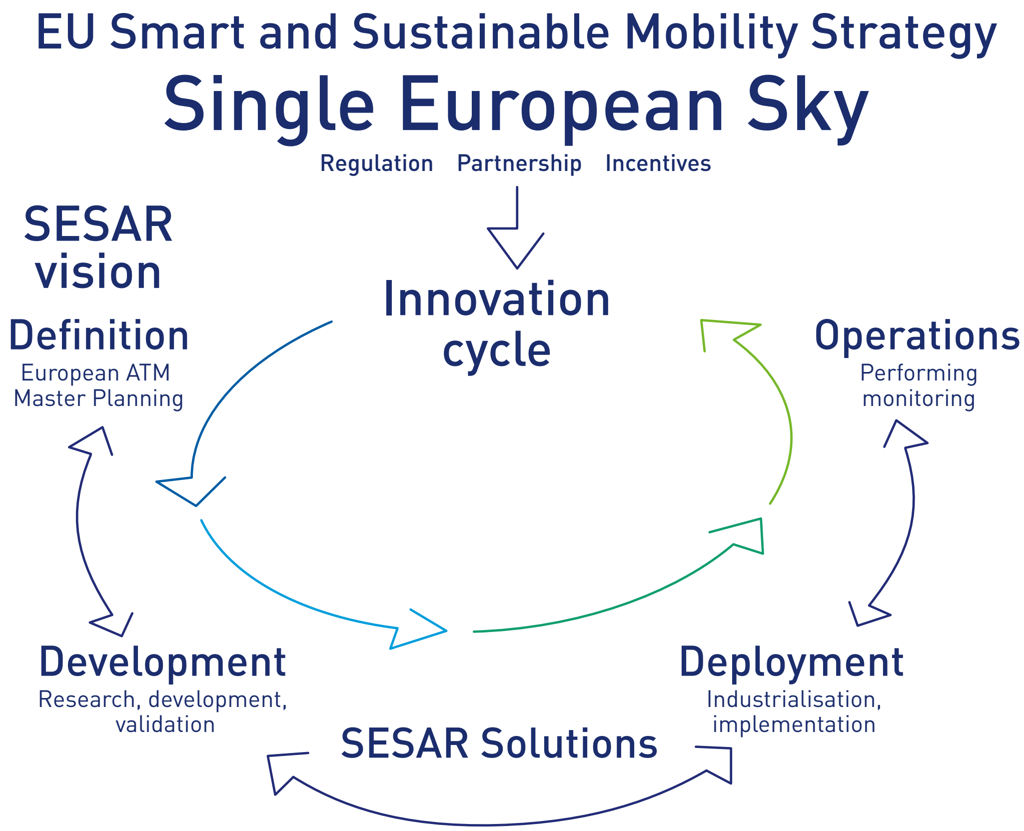
The SESAR project aims to modernise Europe's air and ground ATM infrastructure and operational procedures thus contributing to a smarter, more sustainable, better connected and accessible air transport system. It is an essential enabler for the broader SES initiative. SESAR defines, develops and deploys interoperable ATM solutions aiming to optimise the management of air traffic enabling airspace users to fly safely the most efficient trajectories and to ensure the safe integration of new flying vehicles (such as drones) in all classes of airspace.

[1] SESAR Joint Undertaking, European ATM Master Plan, 2020 edition, Publications Office of the European Union, Luxembourg, 2019.

[2] Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe and repealing Regulations (EC) No 219/2007, (EU) No 557/2014, (EU) No 558/2014, (EU) No 559/2014, (EU) No 560/2014, (EU) No 561/2014 and (EU) No 642/2014

[3] The SESAR 3 JU will also continue to steer and manage the innovation pipeline delivered through the SESAR 2020 Programme. The priority of the SESAR 2020 programme is to close the programme and finalise the delivery of SESAR solutions. However, the scope of the present Multiannual Work Programme is limited only to the implementation of the Digital European Sky. More information about the implementation of the SESAR 2020 Programme can be found in the previous Single Programming Documents, in the Bi-Annual Work Programmes to be adopted by the SESAR 3 JU as well as in the Consolidated Annual Activity Reports.

FIGURE 1: THE SESAR INNOVATION CYCLE



The SESAR project is implemented through an innovation cycle comprising three interrelated phases: definition, development and deployment, the latter includes the industrialisation and implementation processes (see Figure 1).

Although SESAR is a European project, it has gained global recognition as a reference in ATM modernisation. SESAR solutions are exported worldwide and contribute to the standardisation work in the International Civil Aviation Organisation (ICAO). SESAR has provided European industry the opportunity to lead technological innovation in a sector with significant potential for economic growth.

1.2.2. Rationale for the Digital European Sky and the SESAR 3 JU

The aviation ecosystem is changing, starting with the aircraft itself. Soon, conventional aircraft will share the airspace with many other types of air vehicle from ultra-efficient aircraft, airships, drones[4] and air taxis to electric or supersonic aircraft, as well as vehicles operating from spaceports and those flying above commercial aircraft, such as balloons flying at higher altitude, or those used for environmental surveillance or for bringing high-speed internet access to remote areas. Aviation is also expected to become part of an environmentally sustainable intermodal transport network, offering passengers smart travel options and a seamless travel experience. All these changes make for a complex and dense airspace, one that cannot be managed or sustained using the labour-intensive procedures and systems that make up ATM today.

At the same time, the COVID-19-induced hiatus in air travel, which has put at risk an industry essential

[4] EU Regulations 2019/947 and 2019/945 set out the framework for the safe operation of civil drones in the European skies. It defines three categories of civil drone operations: the 'open', the 'specific' and the 'certified' category.

to Europe's economy and connectivity, has given renewed momentum to efforts to build a more resilient business model and infrastructure for aviation. The health crisis, coupled with the climate crisis, has also underlined the need to speed up efforts to make aviation more sustainable for the generations to come. Multiple technology pathways are required, one of which is the digital transformation of aviation's infrastructure (Digital European Sky), the benefits of which could already be felt in the shorter term before the energy transition, with its sustainable aviation fuels and new propulsion systems, comes into play.

The Digital European Sky was first proposed by the SESAR JU in 2017 ([5]), and then formally defined in the 2020 edition of the European ATM Master Plan. Further support for the Digital European Sky was provided by the Wise Persons Group ([6]), established by the European Commission to provide recommendations on the future of the Single European Sky (SES), and a joint declaration by industry ([7]).

The establishment of the SESAR 3 JU and its vision of a Digital European Sky sees the latest digital technologies ('SESAR Solutions') being leveraged to transform Europe's aviation infrastructure (ATM), enabling it to handle the future demand and diversity of air traffic safely and efficiently, while minimising its environmental impact. This transformation centres on technologies that can increase the levels of automation, cybersecure data sharing and connectivity in ATM, as well as the virtualisation of its infrastructure and air traffic service (ATS) provision in all types of airspace, including for very low- and high-altitude operations. In doing so, these technologies enable the system to become more scalable and agile, while building resilience to disruptions, changes in traffic and diversity of air vehicles.

The SESAR 3 JU builds upon the experience of the SESAR JU and continues its coordination role in ATM technology in the EU to further integrate the R & I capacity in Europe. The coordination is expected to include the development of close collaboration and synergies between the SESAR 3 JU's actions and other EU programmes; funding instruments; and relevant initiatives at EU, national and regional levels, in particular with other European partnerships, to achieve greater impact and to ensure the take-up of results.

It is expected that the SESAR 3 JU will contribute to strengthening the competitiveness of Europe's aviation industry (manned and unmanned), facilitating economic recovery and ultimately accelerating the market uptake of innovative solutions to establish European airspace as the most efficient and environmentally friendly sky in which to fly in the world.

1.2.3. Policy context

The SESAR 3 JU supports several important policy initiatives of the EU. First among them is the SES, which seeks to reform the European ATM system with the aim of improving its performance in terms of capacity, safety, efficiency and environmental impact.

As its technological pillar, the SESAR project comprises three interrelated, continuous and evolving collaborative processes ('SESAR life cycle') that define, develop and deploy technological systems and operational procedures in line with the 2020 edition of the European ATM Master Plan, Europe's roadmap for ATM modernisation (see chapter 1.4., 'The European Master Plan: main planning tool for the modernisation of European ATM', below). Within this project framework, the SESAR 3 JU is responsible for the definition and development processes of the SESAR life cycle, establishing, through its work programme, an innovation pipeline through which concepts are transformed into tangible solutions for market uptake.

The establishment of the SESAR 3 JU within the framework of the Horizon Europe programme under the cluster on climate, energy and mobility recognises the contribution of ATM to making aviation more climate- and environment-friendly, more

[5] Digitalising Europe's aviation infrastructure, October 2017.

[6] A report of the Wise Person's Group, established by the European Commission to provide recommendations on the future of the Single European Sky, April 2019.

[7] Joint Stakeholder Declaration for a Digital European Sky, September 2019.

efficient and competitive, smarter, safer and more resilient and the need to address the research to demonstration challenges facing ATM in a partnership with all stakeholders, thus helping bridge the transition towards deployment while engaging ATM stakeholders in these steps.

The ambition of building a Digital European Sky, as defined in the European ATM Master Plan, matches the ambitions of the European Commission's Sustainable and Smart Mobility Strategy, and its European Green Deal and 'Europe fit for the digital age' priorities. All three initiatives have given fresh momentum to the modernisation of aviation in order to achieve the ambitious goal of climate neutrality by 2050. They also make a clear link between digitalisation and the positive role it can play in sustainability and serving people and adding value to their lives.

1.3. Objectives of the SESAR 3 JU

1.3.1. General objectives

The general objectives of the SESAR 3 JU are defined in Articles 4 and 5 of the single basic act, in addition to which the following general objectives are defined in Article 142(1) of the same act:

a) strengthen and integrate the Union's research and innovation capacity in the ATM sector, making it more resilient and scalable to fluctuations in traffic while enabling the seamless operation of all aircraft;

b) strengthen, through innovation, the competitiveness of manned and unmanned air transport in the Union, and ATM services' markets to support economic growth in the Union;

c) develop and accelerate the market uptake of innovative solutions to establish the Single European Sky airspace as the most efficient and environmentally friendly sky to fly in the world.

1.3.2. Specific objectives

The specific objectives of the SESAR 3 JU are defined in Article 142(2) of the single basic act as follows:

a) develop a research and innovation ecosystem covering the entire ATM and U-space airspace (8) value chains allowing to build the Digital European Sky (9) defined in the European ATM Master Plan, enabling the collaboration and coordination needed between air navigation services providers and airspace users to ensure a single harmonised Union ATM system for both manned and unmanned operations;

b) develop and validate ATM solutions supporting high levels of automation;

c) develop and validate the technical architecture (10) of the Digital European Sky;

d) support an accelerated market deployment of innovative solutions through demonstrators;

e) coordinate the prioritisation and planning for the Union's ATM modernisation efforts, based on a consensus-led process among the ATM stakeholders;

f) facilitate the development of standards for the industrialisation of SESAR solutions.

1.3.3. Tasks

The tasks of the SESAR 3 JU defined in Article 143 of the single basic act are the following:

a) coordinate the tasks of the Single European Sky ATM Research (SESAR) definition phase (11), monitor the implementation of the SESAR project and amend, where necessary, the European ATM Master Plan;

b) implement the research and development aspects of the European ATM Master Plan, in particular by:

   (i) organising, coordinating and monitoring the work of the SESAR development phase in accordance with the European ATM Master Plan, including low technology readiness levels (TRL) (0 to 2) research and innovation activities;

   (ii) delivering SESAR solutions, which are deployable outputs of the SESAR development phase introducing new or improved standardised and interoperable operational procedures or technologies;

   (iii) ensuring the involvement of the civil and military stakeholders of the aviation sector, in particular: air navigation service providers, airspace users, professional staff associations, airports, manufacturing industry and the relevant scientific institutions and scientific community;

c) facilitate an accelerated market uptake of SESAR solutions by:

   (i) organising and coordinating large-scale demonstrations activities;

   (ii) coordinating closely with EASA [European Union Aviation Safety Agency] in order to enable timely development by EASA of regulatory measures that fall under the EASA basic regulation (12) and the relevant implementing rules;

   (iii) supporting the related standardisation activities, in close cooperation with standardisation bodies and EASA, as well as with the entity established to coordinate the tasks of the SESAR deployment phase (13) in line with Commission Implementing Regulation (EU) No 409/2013 (14).

8 'U-space airspace' means an unmanned airborne system (UAS) geographical zone designated by Member States, where UAS operations are only allowed to take place with the support of U-space services provided by a U-space service provider.

9 'Digital European Sky ' refers to [the] vision of the European ATM Master Plan, seeking to transform Europe's aviation infrastructure enabling it to handle the future growth and diversity of air traffic safely and efficiently, while minimising environmental impact.

10 'Architecture of the Digital European Sky' refers to the vision of the European ATM Master Plan, seeking to address the current inefficient airspace architecture in the medium to long term by combining airspace configuration and design with technologies to decouple service provision from local infrastructure and progressively increase the levels of collaboration and automation support.

11 The SESAR definition phase means the phase comprising the establishment and updating of the long-term vision of the SESAR project, of the related concept of operations enabling improvements at every stage of flight, of the required essential operational changes within the EATMN [European Air Traffic Management Network] and of the required development and deployment priorities.

12 Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91 (OJ L 212, 22.8.2018).

13 'SESAR deployment phase' means the successive phases of industrialisation and implementation, during which the following activities are conducted: standardisation, production and certification of ground and airborne equipment and processes necessary to implement SESAR solutions (industrialisation); and procurement, installation and putting into service of equipment and systems based on SESAR solutions, including associated operational procedures (implementation).

14 OJ L 123, 4.5.2013, p. 1.

1.4. The European Master Plan: main planning tool for the modernisation of European air traffic management

1.4.1. Context

The European ATM Master Plan is the main planning tool for ATM modernisation across Europe, connecting ATM R & I activities with deployment activities and scenarios to achieve the SES performance objectives and the policy objectives of the EU. The 2020 edition of the Master Plan defines the vision (the 'Digital European Sky') for the SESAR project as a whole (bringing together SESAR development and deployment activities) and related priorities to realise the digital transformation of ATM, making European airspace the most efficient and environmentally friendly sky in which to fly in the world while maintaining safety.

The SESAR 3 JU will be able to develop technical input, assisting the Commission with regulatory activities in the area of ATM, for example by assisting in the preparation of technical documents supporting the common projects established under EU regulation(15), conducting technical studies or supporting standardisation activities.

1.4.2. Master Plan Action Plan

Based on the outcome of the last SESAR 2020 Master Plan Committee, all ATM stakeholders came together to develop an Action Plan composed of 3 practical improvement packages that, if implemented successfully, will significantly simplify and strengthen the Master Plan (MP) process. The scope of the Action Plan is to help direct the successful design of future changes to the MP process providing for each proposed improvement package a clear set of goals, actions and success criteria. The oversight of the successful implementation of this Action Plan is proposed to be ensured by the SESAR 3 JU Governing Board.

The future MP process is proposed to exclusively focus on strategic planning and monitoring of the execution of the SESAR project (i.e. both development and deployment). This implies that the outputs of the MP process will exclusively be tailored to the needs

15 Commission Implementing Regulation (EU) No 409/2013 of 3 May 2013 on the definition of common projects, the establishment of governance and the identification of incentives supporting the implementation of the European Air Traffic Management Master Plan.

of an audience of public (including Member States) and private decision makers while in the past it was targeting a much wider audience (covering both decision makers and experts without fully satisfying either). The future MP process will also provide a more robust outlook on the network performance impact that could be enabled by the rollout of SESAR across all implementing bodies than it ever did in the past.

In areas in which the SESAR 3 JU does not have executive powers (such as the execution of rulemaking or standardisation plans or the deployment programme for Common Projects) the principle of subsidiarity will be applied more strictly whereby the European ATM Master Plan will continue to be recognised as the unique and official strategic reference point for ATM modernisation efforts in Europe, with supporting planning details being left to be handled by the respective organisation in charge of execution. In particular, in the area of SESAR Deployment and within the boundaries of the EU regulatory obligations & tasks of each entity, special attention will be paid to unify processes between the SESAR 3 JU, Eurocontrol (such as ESSIP/LSIPP) and the deployment manager and preserve the strategic value of the MP while also connecting this with actual deployment activities taking or having taken place.

The SESAR 3 JU Governing Board members will benefit from lower administrative burden as formal approvals for changes to the European ATM Master Plan will be limited to pluri-annual update cycles (typically every 3-4 years) unless requested otherwise by the Governing Board. This will enable a full synchronisation of formal adoption cycles between the Union, Eurocontrol and private representatives at the Governing Board. By extension this should also enable a much more solid buy-in from Member States that will play a more direct role also in the implementation of activities of the SESAR 3 JU via the States' Representative Group.

In addition Board members will be provided (for information) on an annual basis with information showing the strategic alignment of SESAR development and deployment activities towards the strategic vision and direction outlined in the European ATM Master Plan in a format that can also be used to stimulate corrective actions where and when appropriate.

The improvements are proposed to be gradually implemented from 2022 and completed in time for the next update of the MP.

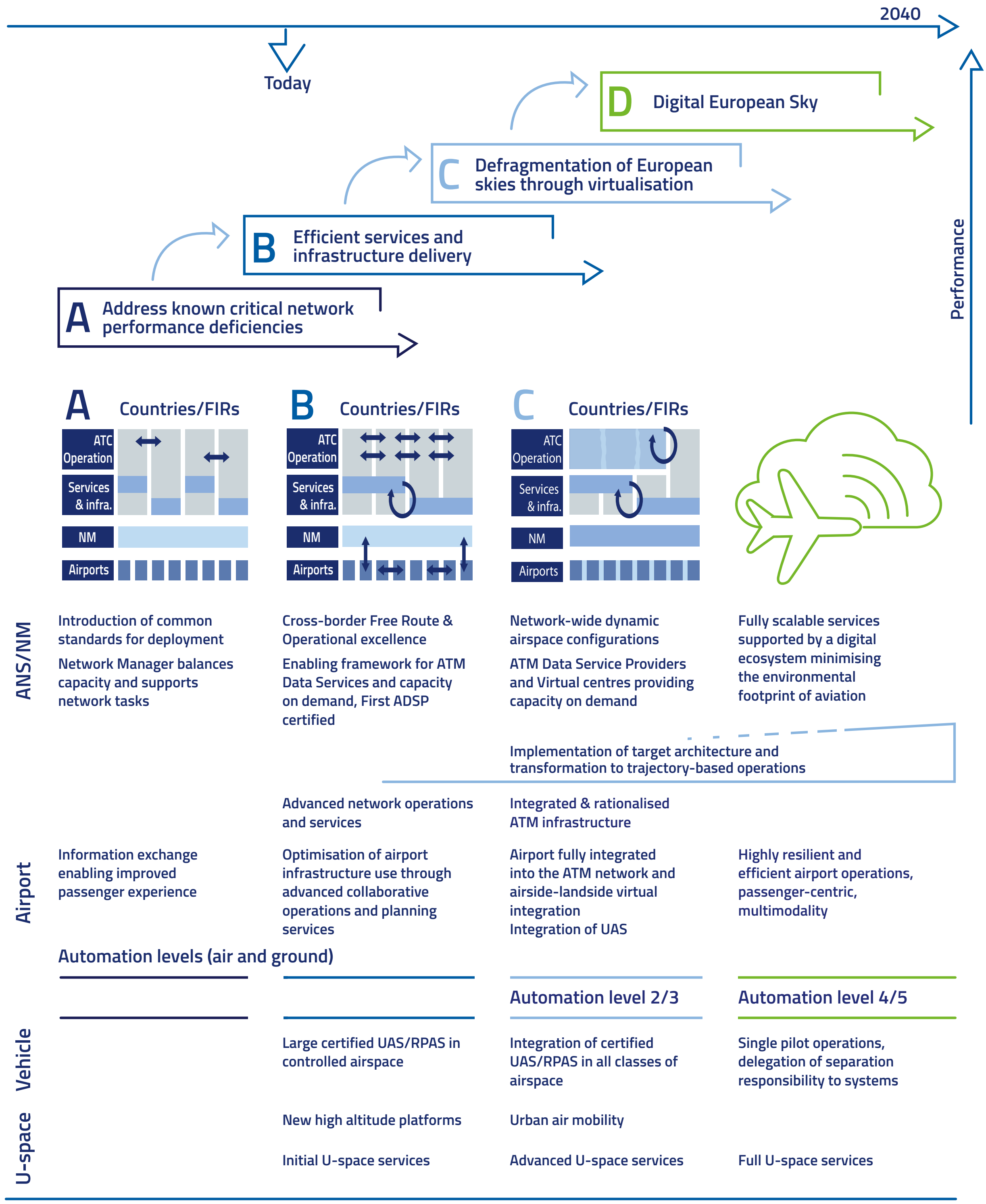
1.5. SESAR delivery: upgrade phases of the European air traffic management system

The delivery of SESAR development and deployment activities contributes to the various phases of the upgrade of the ATM system as outlined in the Master Plan. These phases are depicted in Figure 2.

In relation to the European ATM Master Plan, until 2031, the primary objective of SESAR 3 JU is to deliver the Solutions for phase D at TRL 6 while significantly increasing the market uptake for a critical mass of early movers, focusing on the infrastructure modernisation priorities of phases C and D.

Delivering the digital European sky will bring substantial value for every stakeholder in the aviation value chain; it will also significantly benefit

FIGURE 2: **EUROPEAN ATM SYSTEM UPGRADE PHASES AS PER ATM MASTER PLAN**



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

By investing in innovation, Europe remains competitive and a leader in the global market, delivering state-of-the-art technologies and setting high standards in terms of safety and performance worldwide. According to the European ATM Master Plan, it is estimated that, by 2040, the digital European sky would amount to EUR 80 billion in annual recurring benefits for Europe. Realising the benefits will largely depend on the ability of the sector to create the conditions to shorten the innovation life cycle for infrastructure modernisation. If these conditions are not created, the transformation is likely to be completed only by 2050, with negative implications for the environment, jobs and growth in Europe.

Further information on the performance impact can be found in the Strategic Research and Innovation Agenda (SRIA) (see chapter 4.1).

FIGURE 3: BENEFITS FOR EUROPEAN SOCIETY AND ECONOMY

Zero environmental waste: eliminates ATM environmental inefficiencies caused during operations by the aviation infrastructure, ensuring that it offers solutions that will fully exploit the potential offered by the next-generation aircraft for cleaner and quieter flight

Cyber-resilient: delivers the intended continuity of services despite adverse events.

Safer: relies on the talent of both humans and new technologies to advance the level of safety beyond current levels.

Fully scalable: creates the capacity needed to handle traffic in the most efficient way where and when capacity is needed.

More productive: enables resources (including data) to be shared across the network.

Enabling advanced mobility services: offers smart and personalised mobility options to passengers, allowing them to travel seamlessly and efficiently across modes of transport.

1.6. Mission statement of the SESAR 3 JU

The mission statement of the SESAR 3 JU is as follows:

To accelerate through research and innovation the delivery of an inclusive, resilient and sustainable Digital European Sky.

- Sustainable – establishing Europe as the most efficient and environmentally friendly sky in which to fly in the world.
- Resilient – enabling flexible, scalable, safe and secure ATM that can withstand disruptions in the aviation system.
- Inclusive – integrating and connecting all types of air vehicle and user, including civil and military, manned and unmanned.
- Accelerate – reducing time to market through focused and agile R & I, supporting faster transition to deployment through an extended innovation life cycle.

1.7. Cooperation with the SESAR Deployment Manager

Some SESAR Solutions can require to be mandated for their synchronised implementation. The implementation of these SESAR Solutions will be mandatory by regulation and coordinated when, because of their significant impact on network performance, the need to ensure their timely deployment and address potential local business cases also requires coordination and synchronisation.

This mandatory implementation will be managed through Commission Implementing Regulations - Common projects (CP).

The content of the CPs is developed and proposed by European ATM stakeholders through the SESAR 3 JU and the SESAR Deployment Manager (SDM). Following an assessment and endorsement process of the CP under the European Commission responsibility, a deployment programme is defined by SDM with the aim of implementing the ATM functionalities listed in the CP.

In order to ensure that the deployment programme answers to the ATM Master Plan ambition, an effective transition from the research and innovation to the deployment phase is required. This transition will rely on a strong cooperation and sharing of information between SESAR 3 JU and SDM based on the following guiding principles :

- Creation of synergies where possible and be complementary to each other's activities to the largest possible extent;
- Effective cooperation and communications ensuring mutual and timely sharing of relevant information;
- use mechanism of cooperation where possible with regard to the necessary connections between SESAR research, development, innovation and SESAR deployment activities.

2. MULTIANNUAL WORK PROGRAMME

The multiannual work programme of the SESAR 3 JU is designed to achieve the general and specific objectives set out in the SESAR 3 JU's basic act, as detailed above in chapter 1.3, 'Objectives of the SESAR 3 JU', above, and to deliver the Solutions for phase D of the European ATM Master Plan, shown in chapter 1.5, 'SESAR delivery: upgrade phases of the European ATM system', above.

2.1. Overall plan of activities from 2021 to 2031

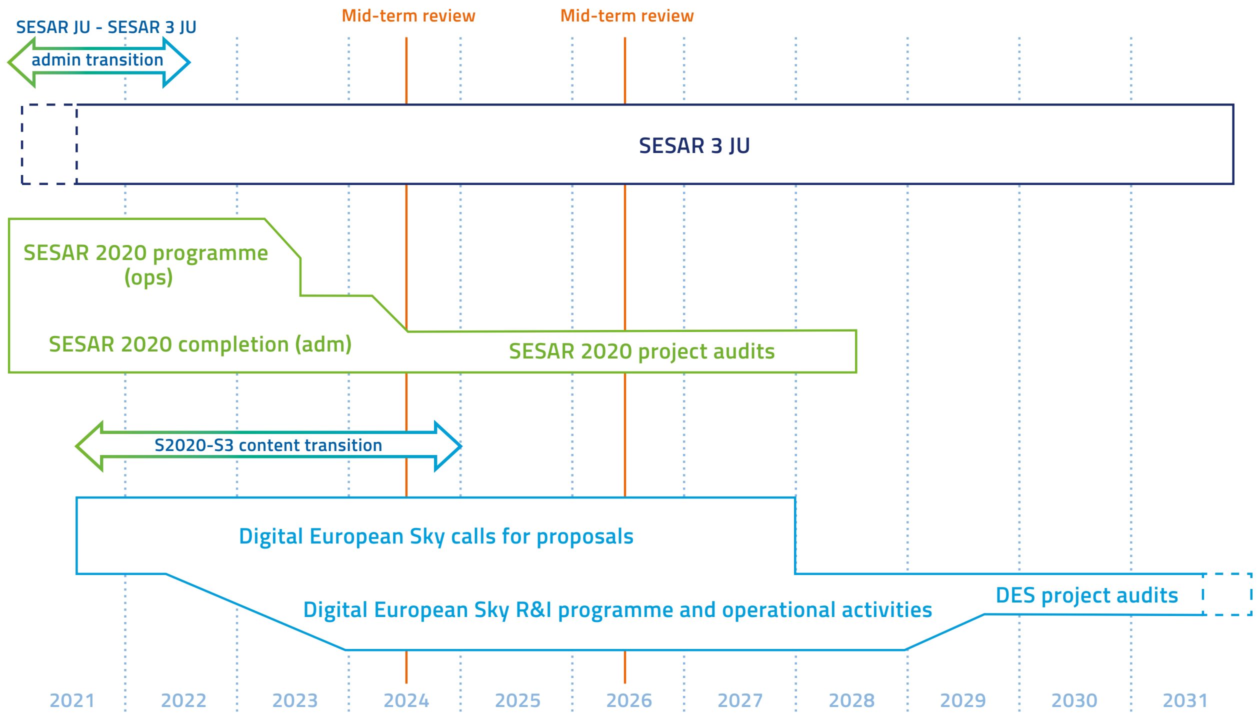
As depicted in Figure 4, from 2021 to 2031, the SESAR 3 JU will complete the following tasks.

- Carry out the final stage of the SESAR 2020 programme, taken over from the SESAR JU in the course of 2021. The R & I activities of the SESAR 2020 programme will be carried out under the existing regulatory framework, namely Horizon 2020.
- Design and implement the Digital European Sky R & I programme, under the principles and framework laid down in this document.
- Carry out operational activities other than the Digital European Sky programme, in relation to outreach (stakeholder engagement, cooperation with third countries and international organisations), data and dissemination.
- Deliver activities to fulfil its corporate, administrative, legal and financial obligations.

2.2. The Digital European Sky research and innovation programme

The Digital European Sky programme will consist of a number of coordinated projects awarded as a result of multiple calls for proposals (see paragraph 2.2.3,

FIGURE 4: OVERALL ACTIVITY PLAN OF THE SESAR 3 JU 2021–2031



'Calls for proposals' below). The scope of the projects is intended to cover the SRIA, with the live projects having minimal dependencies on each other, but all focusing on delivering SESAR Solutions and Digital European Sky outcomes in accordance with the ATM Master Plan. Thus, the programme is heavily outcome-oriented and, as a result, progress is coordinated by the SESAR 3 JU. This is described in more detail in the following paragraphs.

The SESAR 3 JU recognises the uncertainties inherent within R & I, especially when performed at low maturity levels, when the proposed exit maturity may not be reached or even when the proposed ATM application is found to be unsuitable. To this end, the SESAR 3 JU will coordinate and appoint its own focal points for grant management, programme management and programme expertise, and so applicants will be informed of the need to regularly coordinate with the SESAR 3 JU to maintain visibility for managing expectations and documenting/exploiting unexpected outcomes.

2.2.1. The SESAR innovation pipeline

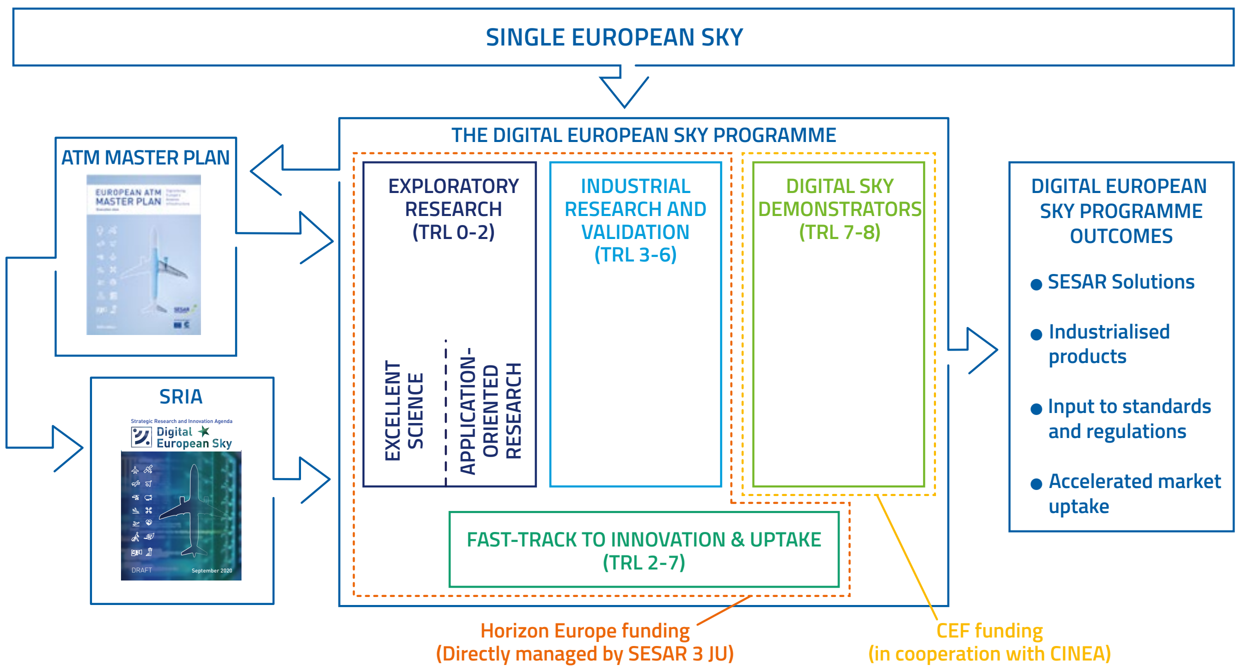
The SESAR 3 JU plays a central role in concentrating, driving and coordinating ATM research in the EU to achieve the objectives of the SES developed in the Master Plan. Continuing the approach developed through the SESAR 1 and the SESAR 2020 programmes run from 2009 to mid-2023, the Digital European Sky Programme is structured into three main R & I phases (Exploratory Research, Industrial Research and Validation and Digital Sky Demonstrators) that aim to deliver the thematics defined in the SRIA ([16]). Known as the SESAR innovation pipeline, this structure sees operational and technology solutions mature progressively through Technology Readiness Levels (TRLs).

For the Digital European Sky programme, the pipeline is constructed from four categories of activities; categories 2 and 3 are within the Industrial Research Phase phase ([17]):

1. Exploratory Research (TRL 0–2), funded under Horizon Europe for the EU part;
2. Industrial Research and Validation (TRL 3–6), funded under Horizon Europe for the EU part;
3. Fast-Track Innovation and Uptake(TRL 2–7), funded under Horizon Europe for the EU part;
4. Digital Sky Demonstrators (TRL 7 and 8), funded under the Connecting Europe Facility (CEF) for the EU part ([18]), in collaboration with CINEA.

The four categories of activity, including their full scope, are shown in Figure 5 and are further described below. They enable a best-practice managed approach that

FIGURE 5: **THE SESAR INNOVATION PIPELINE**



[16] SRIA details the R & I roadmaps to achieving the Digital European Sky. The document is available on the SESAR 3 JU website.

[17] The indicated source of funding is further detailed in Sections 2.2.3 and 2.2.3.3, and in Chapter 4.

[18] Within the Digital European Sky Programme, Digital Sky Demonstrators are subject of a specific working arrangement In this arrangement, the SESAR 3 JU ensures the strategic orientation of the projects and provides technical advice to the European Commission, in coordination with the European Climate, Infrastructure and Environment Executive Agency (CINEA), which manages the calls for proposals and the resulting grants. This working arrangement is described in Section 2.2.3.

is suited to the needs of the SESAR R & I activities to be performed, and that is at the applicable level of research maturity. The innovation pipeline allows for both a more traditional 'waterfall' development method and iterative developments; and is primarily focused on 'fast-track innovation and uptake'. The innovation pipeline will make it possible to rapidly transition from exploration (low TRL) to validation, thus enabling accelerated progression to demonstration (high TRL) and transition to the market.

2.2.1.1. Research maturity

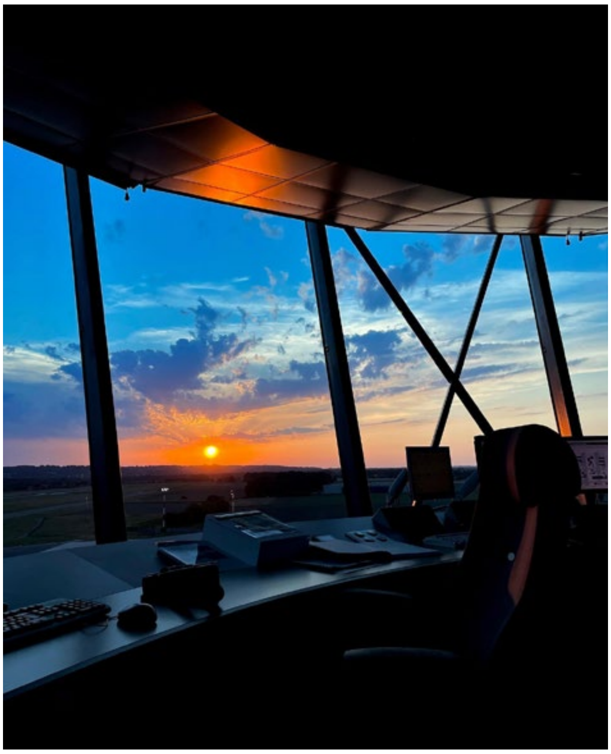
The Digital European Sky programme is researching and developing not only technologies, but also systems and operations. To monitor progress towards a proposed exit maturity, the SESAR 3 JU will use TRLs and gates to control these exit maturity levels across the innovation pipeline. The SESAR 3 JU will also communicate its achievements in delivering increased maturity/readiness externally using the same approach. TRLs correspond to specific categories of research activities; the level of achievement and consequent maturity of category is described as follows.

Exploratory Research covers the following:

- Pre TRL 1: scientific research: fundamental exploratory scientific research investigating relevant scientific subjects and conducting feasibility studies looking for potential application areas in ATM, concentrating both on outreach to other disciplines and on educating researchers and sharing experience within the scientific community.
- TRL 1: basic principles observed and reported: exploring the transition from scientific research to applied research by bringing together a wide range of stakeholders to investigate the essential characteristics and behaviours of applications, systems and architectures. Descriptive tools are mathematical formulations or algorithms.
- TRL 2: technology concept and/or application formulated: SESAR application-oriented research. Theory and scientific principles are focused on very specific application area(s) to perform the analysis to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.

Industrial Research and validation covers the following:

- TRL 2: technology concept and/or application formulated: this is applicable when an early maturity application/concept is proposed and may include mature technology elements with the objective to build a rapid demonstrable environment to help validate the application of the concept and better understand the operational benefits and overall maturity of the proposed development path.



- TRL 3: analytical and experimental critical function and/or characteristic proof of concept: proof of concept validation. Active research and development (R & D) is initiated with analytical and laboratory studies, including verification of technical feasibility using early prototype implementations that are exercised with representative data.
- TRL 4: component/subsystem validation in laboratory environment: stand-alone prototyping implementation and test with integration of technology elements and conducting experiments with full-scale problems or data sets.
- TRL 5: system/subsystem/component validation in relevant environment: thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
- TRL 6: system/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space): some large-scale demonstration and validation activities organised to validate prototyping implementations and draft standards on full-scale realistic problems using partial integration with existing systems. While limited documentation is available, the engineering feasibility is fully demonstrated in actual system application.
- TRL 7: system demonstration in an operational environment (ground, airborne or space) (only in Fast Track Innovation and Uptake): the system is at, or near, scale of the operational system, with most

functions available for demonstration and test. Well-integrated with collateral and ancillary systems, although limited documentation available. This demonstration level may be achieved by fast-track innovation and uptake projects when progressive iterative demonstrations towards TRL 7 is the principle upon which the methodology is based.

Digital Sky Demonstrators covers deployment up to the following:

- TRL 7: system demonstration in an operational environment (ground, airborne or space): the system is at, or near, scale of the operational system, with most functions available for demonstration and test. Well-integrated with collateral and ancillary systems, although limited documentation available.
- TRL 8: actual system completed and 'mission qualified' through test and demonstration in an operational environment (ground or airborne): end of system development. Fully integrated with relevant operational systems (people, processes, hardware and software); most user documentation, training documentation and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification, validation and demonstration completed; regulatory needs and standards finalised.

2.2.1.2. Research and innovation activities within the innovation pipeline

Exploratory research

Fully funded under Horizon Europe, Exploratory Research drives the development and evaluation of innovative or unconventional ideas, concepts, methods and technologies that can define and deliver the performance required for the next generation of European ATM systems. Activities cover low TRL research and are divided into two distinct maturity subphases. The first subphase is 'excellent science' and is primarily oriented at universities and research organisations to create a coordinated body of ideas, using a knowledge transfer network, and consists of early research, which leads to the second subphase, called 'application-oriented research', which takes the most promising ideas and applies them to an area of ATM where there is potential to exploit the idea(s) to deliver future operational benefit.

This research helps to mature new concepts for ATM beyond those identified in the ATM Master Plan, as well as to mature emerging technologies, operations and methods to the level of maturity required to feed the applied research conducted in the Industrial Research and Validation phase. The target maturity at the end of this phase is TRL 2 and comprises the following:

- pre TRL 1: scientific research,
- TRL 1: basic principles observed and reported,
- TRL 2: technology concept and/or application formulated.

Industrial research and validation

Fully funded under Horizon Europe, these R & I activities include applied research, pre-industrial development and the necessary validation activities. These activities typically start at TRL 3 and are progressively progressed up to TRL 6, and comprise the following:

- TRL 3: analytical and experimental critical function and/or characteristic proof of concept,
- TRL 4: component/subsystem validation in laboratory environment,
- TRL 5: system/subsystem/component validation in relevant environment,
- TRL 6: system/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space).

The development methodology inherent in this approach will result in a progressive increase in assessed maturity over time, along with the required deliverable material developed to describe the anticipated SESAR Solution, its achievable performance and completion of the exit maturity that was proposed at the outset.

Fast-Track Innovation and Uptake (Fast Track)

Fully funded under Horizon Europe, this thread is designed to accelerate the development of high-risk / high-gain projects with the perspective of shortening the time to market for disruptive and highly innovative solutions. These activities may start at very low TRLs (from TRL 2), but should target delivering, as rapidly as possibly, new products and services to the market at TRL 7 (system demonstration in an operational environment). Fast-track projects should demonstrate the application of development methods, including an iterative approach with fast prototyping to rapidly test the desirability, feasibility and viability of new services and technologies with end users.

The SESAR 3 JU will not prescribe a particular iterative model or rapid prototyping method; this choice is to be made by applicants to the topics described in the respective call(s). To facilitate this approach, no traditional interim control gates will be mandated, in the sense of a progressive maturity used in the rest of Industrial Research, although the applicant is expected to state the maturity at the start of activities, to describe their development approach to illustrate how they propose to manage transition towards expected outcome(s) and to commit to supporting the proposed maturity (TRL) exit gate. See subparagraph 2.2.1.3, 'Exit Maturity Gates to control project delivery', below.

The starting maturity for a project in Fast Track can be from TRL 2 upwards, although, as the starting TRL increases, the benefits of an iterative approach tend to diminish. Given the iterative approach from low TRLs, Fast Track, unlike the rest of Industrial Research, may also increase its TRL assessment as work progresses, but then fall back to a lower TRL as the proposed concept and solution is further understood in a representative environment – and this is quite normal. Therefore, assessment of the maturity level during the execution of the project will need to be adapted to ensure that relevant questions and checklists are used and that maturity may reduce from one assessment to the next and not be a problem, so long as causal factors and next steps are understood. Over a longer assessment period, there will still be a progressive increase of the TRL towards the TRL-7 target, as the technology/concept and understanding of the operational opportunity come from the results of the project.

The SESAR 3 JU will select topics that best align with the Fast Track approach and will reserve a budget for these activities within the Industrial Research phase.

Digital Sky Demonstrators

Many of the innovations needed to deliver the digital European sky are not 'business as usual', but breakthrough solutions that combine digital and physical infrastructure capabilities. Bringing these innovations to scale in the market is challenging, considering the high degree of technological, regulatory or market risk the aviation industry faces, which has so far deterred or delayed private investment in its infrastructure.

Fully funded under the CEF (see paragraph 4.2.1, 'Union financial contribution', below) in cooperation with CINEA (the European Climate, Infrastructure and Environment Executive Agency), a first set of large-scale digital sky demonstrators offers a viable means to build confidence and to bridge from research through industrialisation to implementation. As such, the demonstrators will be closely connected to the standardisation and regulatory activities, and will provide a platform for a critical mass of 'early movers', representing a minimum of 20 % of the targeted operating environment, to accelerate market uptake (subject to available funding). Demonstrators will take place in live operational environments and put to the test the concepts, services, technologies and standards necessary to deliver the digital European sky. This will help create buy-in from the supervisory authorities and operational staff, providing tangible evidence of the performance benefits in terms of environment, capacity, safety, security and affordability. Typically, these activities address up to TRL 8. This covers the following:

- TRL 7: system demonstration in an operational environment (ground, airborne or space),
- TRL 8: actual system completed and 'mission qualified' through test and demonstration in an operational environment (ground or airborne).

The applicable TRLs are further defined in subparagraph 2.2.1.1.

2.2.1.3. Exit maturity gates to control project delivery

To guarantee the delivery of robust SESAR Solutions, the maturity achieved during the development life cycle will be assessed during the applicable exit maturity gates. Project maturity self-assessment will also be required as input to the yearly project review to allow SESAR 3 JU to monitor the progress of a solution's development. A set of maturity criteria, compliant with the Horizon Europe TRL definition, will be used to confirm the maturity level reached by the SESAR Solution. These criteria can be found in Annex E 'Maturity criteria'.

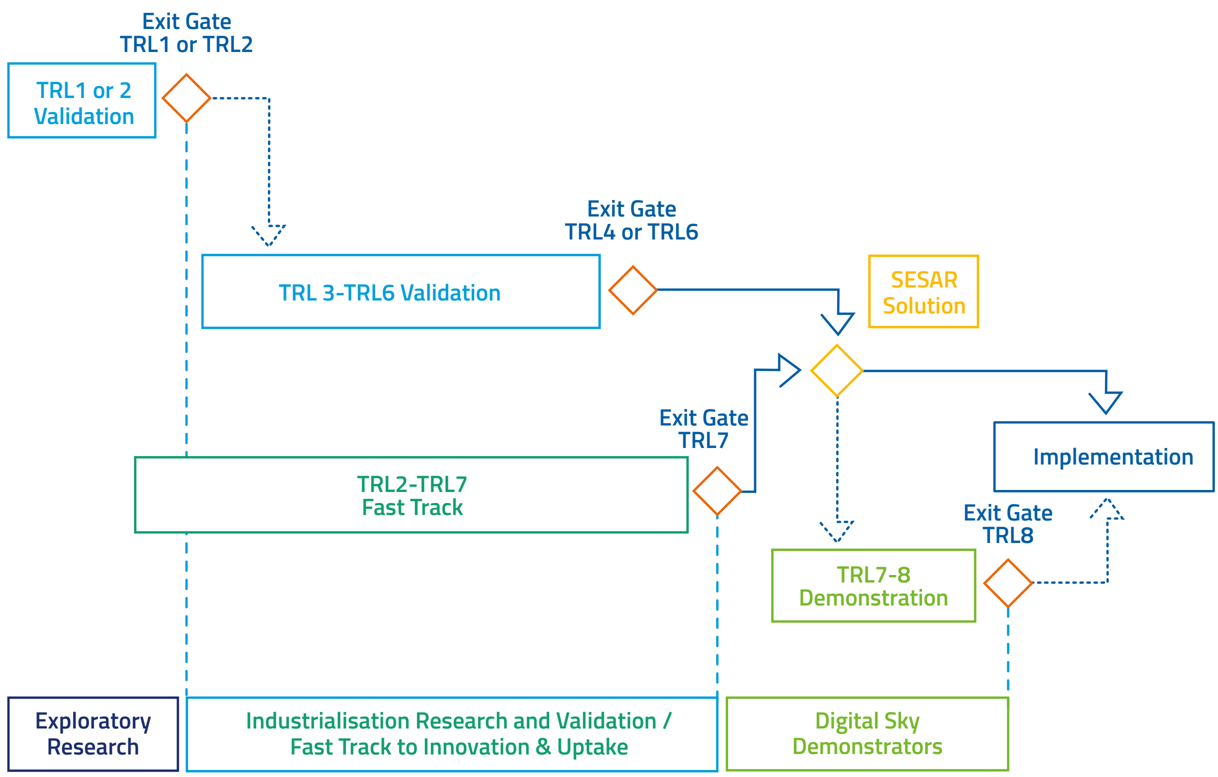
As required by Horizon Europe, the targeted TRL of each topic will be identified, together with the preferable starting TRL. The targeted TRL will represent the minimum expected maturity to be achieved by the project activities. Should the development of the solution be faster than initially planned, a higher maturity level could be targeted by the project, leading to applying the required maturity criteria accordingly. Should the expected maturity level not be achieved, the delivered maturity level will have to be duly justified and will have to be confirmed through an applicable exit maturity gate. In particular, a SESAR Solution reaching TRL4 at the exit maturity gate will therefore require further work to validate it and ensure getting TRL6 maturity before being considered as a SESAR Solution ready for implementation.

The maturity gate overview is shown in the simplified diagram in Figure 6.

2.2.1.4. Expected outputs of the Digital European Sky research and innovation programme

Table 1 summarises the main activities performed and the main outputs delivered in each of the activity categories of the R & I programme.

FIGURE 6: **MATURITY GATES ARE USED TO CONTROL PROJECT DELIVERY**



This high-level view of the expected outcomes can be further described in terms of concrete technical deliverables that a project will have to submit to SESAR 3 JU. These technical deliverables will aim to capture the required elements to be further validated across the R & I pipeline and when full maturity is achieved, and to guarantee the delivery of SESAR Solutions as deployable outputs. These deliverables will therefore mainly address the operational requirements and technical specifications, the performance assessment, the cost–benefit analysis and the contribution to standardisation and identification of regulatory needs.

TABLE 1: EXPECTED OUTPUT PER PHASE OF THE SESAR INNOVATION PIPELINE

R & I pillar	TRL	Activities	Expected outputs
EXPLORATORY RESEARCH	TRLS 0–2	▸ Scientific studies ▸ Application-related studies with mathematical formulations and algorithms ▸ Concept analysis in specific application areas	▸ Expression of the basic principles intended for use ▸ Potential applications identified and formulated ▸ Preliminary conceptual design, providing understanding of how the basic principles would be used
INDUSTRIAL RESEARCH AND VALIDATION	TRLS 3–6	▸ Proof-of-concept validation and feasibility studies ▸ Laboratory testing ▸ Prototype development and testing in a high-fidelity laboratory environment or in a simulated operational environment (TRL 6) ▸ Demonstration of an actual system prototype in an operational environment (TRL 7)	▸ SESAR solutions (new or improved standardised and interoperable operational procedures and/or technologies) ready for industrialisation: ▸ performance requirements and technical specifications ▸ performance benefits validated in the relevant environment and positive cost–benefit analysis ▸ contribution to standards and regulations
FAST-TRACK INNOVATION AND UPTAKE	TRLS 2–7		
DIGITAL SKY DEMONSTRATORS	TRLS 7 AND 8	▸ Final solution demonstration in operational environment fully integrated with operational systems (TRL 8)	▸ SESAR solutions ready for wider-scale implementation across Europe: ▸ significant contribution to completed standards and regulatory framework

Table 2 lists and defines all the Digital European Sky programme technical deliverables.

TABLE 2: THE DIGITAL EUROPEAN SKY PROGRAMME DELIVERABLES

Deliverable	Definition
CBA	The cost-benefit analysis documents the potential benefits, when deployed in the applicable environment(s), of a SESAR ATM Solution or a SESAR technological solution (CBAT), and whether or not they are expected to exceed the costs over a given time horizon.
CONCEPT OUTLINE	High level description of the concept with identification of potential benefits and associated risks.
CONTEXTUAL NOTE	The contextual note provides to any interested reader (external and internal to the SESAR programme) an introduction to the SESAR Solution in terms of scope, main operational and performance benefits, relevant system impacts, etc. When the Solution is at TRL6 level it contains as well recommendations regarding additional activities to be conducted during the industrialisation phase or as part of deployment. It introduces the technical data pack comprising the SESAR 3 JU deliverables.
DEMOP	The demonstration plan describes the way in which one or more demonstration exercises or activities is to be prepared and executed in order to achieve the demonstration objectives. It includes those demonstration exercises that are required and sufficient to ensure that the SESAR solution(s) under the scope of the project will progress from the initial maturity level to the target one. As appendix, it includes the required transversal and performance assessment plans (e.g. safety, human performance).
DEMOR	The demonstration report consolidates the results obtained by demonstration exercises. As appendix, it includes the transversal assessments (safety, security, human performance & environment impact assessments) and any update on the requirements (SPR-INTEROP/OSED, TS/IRS) for the SESAR solutions under the scope of the demonstration project.
ECO-EVAL	The economic evaluation assesses the potential benefits that an innovative idea or application under analysis by an exploratory research project could provide against an initial high level estimation of the costs that may imply.
ERP	The exploratory research plan describes the way in which one or more validation exercises or activities are to be prepared and executed in order to achieve the validation objectives of an exploratory research project
ERR	The exploratory research report consolidates the results obtained by an exploratory research project once the validation activities, experiments, etc. have been completed.
FRD	The functional requirements document represents a formal statement of a SESAR technological solution related functional requirements. The content describes 'what' the SESAR technological solution has to do but not the 'how'.
OSED	The operational service and environment description aims at describing the specific activities and interactions of various stakeholders related to a new concept of operations or to a new piece of existing concept.
REG	Proposed SESAR acceptable means of compliance to EASA to illustrate means to establish compliance with the Basic Regulation and its Implementing Rules
SPR-INTEROP/ OSED	The SPR-INTEROP/OSED contains the safety and performance requirements (SPR) and interoperability requirements (INTEROP), related to a SESAR solution, which have been defined and validated in the context of the operational service and environment description (OSED), which describes the applicable environment, assumptions, etc. As appendix, it includes the transversal assessments and the performance assessment report that justify the SPR-INTEROP requirements (e.g. safety, human performance).
STAND	Proposed SESAR input to standardisation activities (e.g. EUROCAE, European Organisation for Civil Aviation Equipment).

Table 3 allocates the deliverables per phase of the R & I pipeline. These deliverables will be reviewed and assessed from both quality and maturity perspectives by the SESAR 3 JU.

TABLE 3: DIGITAL EUROPEAN SKY DELIVERABLES MAPPED WITH PHASES OF THE INNOVATION PIPELINE

Deliverables	Fundamental Tesearch	Applied Oriented Research	Industrial Research	Fast Track Innovation & Uptake	Digital Sky Demonstrators
Concept Outline	■				
ERP	■	■			
ERR	■	■			
FRD		■			
OSED		■			
ECO-EVAL		■			
Contextual Note			■	■	
SPR-INTEROP/ OSED			■	■	
TS/IRS			■	■	
VALP			■	■	
VALR			■	■	
CBA			■	■	
DEMOP					■
DEMOR					■
STAND			■	■	■
REG			■	■	■

The projects will be strongly encouraged to schedule the submission of draft deliverables along the life cycle of the R & I activities. This approach will de-risk any possible rejection of the deliverables should the quality of the documents not be up to standard.

Although the responsibility of conducting the performance assessments and CBAs lies with the Digital European Sky projects for the Solutions they develop, the SESAR 3 JU will process these necessary performance assessments and aggregate them through a transversal performance evaluation process addressing the whole European Network that covers sets of mature Solutions with the objective to monitor progress and identify potential research delivery gaps towards achieving the Performance Ambitions as defined in the European ATM Master Plan.

2.2.1.5. Strengthening standardisation

An essential phase of the SESAR innovation cycle is the transition of the Solutions from the research and validation to the deployment (i.e. industrialisation phase). One of the most critical aspects of the transition is the development of mature and robust standards which will support both the industrialisation of the systems, procedures or services in question, and provide the basis for means of compliance for any neccessary regulations.

It is essential that SESAR 3 JU projects include activities aiming at identifying the needs for standards and at developing accordingly the required specifications for further consideration by the Standardisation Bodies (e.g. EUROCAE). Therefore, the SESAR 3 JU will ensure

close monitoring of the project's activities related to standardisation in facilitating the coordination between the projects and the related standardisation bodies. To secure the consideration of standardisation needs and support its execution, the SESAR 3 JU will develop a technical deliverable in close coordination with EUROCAE. This technical deliverable will provide the required input for developing the related standards. The STAND deliverable submitted by the project across the development of the SESAR Solution will be reviewed by SESAR 3 JU to guarantee its quality and maturity. In particular, specific maturity criteria addressing the standardisation have been defined as of TRL2 and will be applied by SESAR 3 JU during the Maturity Gates (see Annex E). In addition, the standardisation needs will be consolidated and included in the ATM Master Plan level 3 plan delivered on a regular basis by the SESAR 3 JU.

These standardisation activities at DES programme level will be complemented by the SESAR 3 JU participation to the EUROCAE Council and the Technical Advisory Committee, to the European ATM Standards Coordination Group and the European UAS Standards Coordination Group as described in the section 2.3.2.2 Industry stakeholders.

This structured approach starting as soon as possible during the development and validation of the solution and closely monitored by the SESAR 3 JU at Programme level and supported by SESAR 3 JU at standardisation governance level will allow R&I and pre-implementation activities to be intensified leading to accelerating SESAR market uptake.

2.2.1.6. Certification of new technologies

EASA may be invited by applicants, beneficiaries or the Executive Director to advise on individual projects and demonstration activities on issues related to compliance with aviation safety, interoperability and environmental standards, to ensure that these lead to the timely development of relevant standards, testing capacity and regulatory requirements for product development and deployment of new technologies.

Considered as compliance with applicable requirements, certification should be sought as early as possible within the maturity progress of the SESAR Solution. This will ensure that all safety and operational risks are mitigated and will avoid unnecessary delays in the transition to deployment.

2.2.2. Research and innovation needs addressed in the Digital European Sky programme

The SRIA presents the strategic R & I roadmaps for 2021–2027 to deliver on the implementation of the Digital European Sky (i.e. fully scalable services supported by a digital ecosystem minimising the environmental footprint of aviation), including the integration of drones, matching the ambitions of the European Green Deal and the 'Europe fit for the digital age' initiative.

The activities outlined in the SRIA to build a digitalised infrastructure are also critical for a post-COVID-19 recovery, enabling aviation to become more scalable, economically sustainable, environmentally efficient and predictable.

To achieve the Digital European Sky (phase D of the European ATM Master Plan), nine R & I flagships (referred to as 'destinations' in Horizon Europe) have been identified in the SRIA, along with their underlying R & I needs/challenges ([19]). These will be the basis for identifying future Solutions addressing phase D of the upgrade of the European ATM system, as targeted by the Digital European Sky. The nine flagships are listed below, with the related 59 R & I needs, which are described in more detail in the Appendix B 'SRIA flagships and their R & I needs':

1. Connected and automated ATM. The Digital European Sky vision recognises that the future ATM environment will be increasingly complex, with new airspace vehicles flying at different speeds and altitudes, compared with conventional aircraft. Moreover, there will be increasing pressure to reduce the costs of the ATM infrastructure while improving performance. Secure

[19] The Master Plan states explicitly that the essential operational changes (EOCs) are defined only for elements that are 'in the pipeline towards deployment' (phases A–C), and are therefore not defined for phase D, which is the central focus of SESAR 3. The nine flagships identified in SRIA (the how) were derived from the phase D vision defined in the Master Plan (which focused on the why, what and when).

data-sharing between all the components of the ATM infrastructure and the relevant stakeholders is a key part of the Digital European Sky, together with automation using the shared data to improve ATM performance. This flagship identifies the specific research needed to realise the automation and connectivity vision of the European ATM Master Plan for the future ATM ground system

Expected impact. These activities will boost the level of automation that can be achieved for the relevant areas. This will contribute to achieving the European ATM Master Plan vision to reach at least level 2 (task execution support) for all ATC tasks and up to level 4 (high automation) for some of the tasks. The impact for U-space services will be even higher, where the aspiration is between level 4 and level 5 (full automation) for all the relevant tasks. Higher levels of automation are considered an essential enabler for increasing the performance of the sociotechnical ATM system.

An affordable and service-oriented way of sharing trajectories across ATM actors will be available, thereby enabling the capacity, cost-efficiency, operational efficiency and environmental performance ambitions of the European ATM Master Plan for controlled airspace and airports. Unmanned traffic will have been integrated with manned traffic where required and will utilise additional airspace resources where available in an efficient and safe manner.

The future ATM system will deliver hyperconnectivity between all stakeholders (vehicle to vehicle, vehicle to infrastructure) via high-bandwidth, low-latency ground-based and satellite networks. Highly automated systems with numerous actors will interact with each other seamlessly, with fewer errors, making the system scalable and even safer than today.

2. Air–ground integration and autonomy. ATM needs to evolve, by exploiting existing technologies as much as possible, and developing new ones in order to increase global ATM performance in terms of capacity, operational efficiency and accommodation of new and/or more autonomous air vehicles, that is supporting the evolving demand in terms of diversity and complexity, from very low-level (VLL) airspace to high-level operations. This progressive move towards autonomous flying, enabled by self-piloting technologies, requires closer integration and advanced means of communication between vehicle and infrastructure capabilities so that the infrastructure can act as a digital twin of the aircraft. Ultimately, manned and unmanned aerial vehicles (UAVs) should operate in a seamless and safe environment using common infrastructure and services supporting a common concept of trajectory-based operations (TBO). Future operations should therefore rely on direct interactions between air and ground automation, with the human role focused on strategic decision-making while monitoring automation.

Expected impact. The air–ground integration supported by automation levels 2/3, and then 4/5, will enable the implementation of target architecture and transformation to TBO (ATM Master Plan phases C and D). In particular, the integration of certified drones into all classes of airspace will be achieved thanks to increased automation and delegation of separation responsibility to systems. In addition to full U-space services, single-pilot operations (SPO) will be rendered possible

3. Capacity-on-demand and dynamic airspace. For the last few decades, capacity has not been available when and where needed and it has often been available when and where not needed. The number of new airspace users, including RPAS / higher airspace operations (HAO) traffic, will increase by 2030 and will require an increased level of capacity, and an increased level of variability in that capacity. Integrated ATM requires agility and flexibility in providing capacity where and when it is needed, particularly for maximising the use and performance of limited resources, that is airspace and air traffic control officers (ATCOs). It will require the dynamic reconfiguration of resources and new capacity-on-demand services to maintain safe, resilient, smooth and efficient air transport operations while allowing for the optimisation of trajectories, even at busy periods.

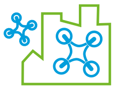
Expected impact. By providing capacity dynamically where and when it is needed and reconfiguring the airspace to match the traffic flows, overall system resilience and flexibility are increased significantly. Predictability (from an airline and airport scheduling perspective) is ensured by a more stable and predictable level of capacity in all-weather operations.

Peak runway throughput increases could deliver improved exploitation of the airport in terms of both airport slot increases (in the scheduling phase) and on-time operations.

The optimisation of trajectories helps to reduce fuel burn and increases predictability, thereby contributing to flight efficiency, reducing the environmental impact and enhancing the passenger experience.

The establishment of the common network performance cockpit, following the definition of appropriate key performance areas for the performance of the airspace, will allow an increased level of connectivity, providing new opportunities for revenue generation and for business between European regions.

An increased level of ATCO productivity will make it possible to manage traffic growth with the current level of resources, thus improving cost efficiency.



4. U-space and urban air mobility. Over the next 10 years, the implementation of the SRIA aims to unlock the potential of the drone economy and enable urban air mobility (UAM)[20] on a wide scale. To that end, a new ATM concept for low-altitude operations needs to be put in place to safely cater for the unprecedented complexity and high volume of the operations that are expected. This concept, referred to as U-space, will include new digital services and operational procedures, and its development has already started within the SESAR 2020 programme. U-space is expected to provide the means to manage safely and efficiently high-density traffic at low altitudes involving heterogeneous vehicles (small UAVs, electric vertical take-off and landing (eVTOL) aircraft and conventional manned aircraft), including operations over populated areas and within controlled airspace. U-space will have to integrate seamlessly with the ATM system to ensure safe and fair access to airspace for all airspace users, including UAM flights departing from airports.

Expected impact. The assumption made in the European ATM Master Plan 2020 edition is that the coordinated development and deployment of U-space is key to realising in a timely manner the economic benefits anticipated in the 2016 European drones outlook study. In addition, the assumption is that U-space will not have a negative effect on the Master Plan performance ambitions for the European ATM system. This holds specifically true for the ambitions relating to safety, security, capacity (notably at airports) and cost efficiency.

Specific performance metrics for measuring the efficiency of U-space service provision need to be developed as part of the U-space R & I and will result in a specific U-space performance framework. This will not only ensure that U-space service provisions can be properly evaluated, but will also enable an assessment of the additional benefits obtained through the coordinated development of such services.

5. Virtualisation and cybersecure data-sharing. The Airspace Architecture Study clearly highlighted the lack of flexibility in the sector configuration capabilities at pan-European level. This is caused by the close coupling of ATM service provision to the ATS systems and operational procedures, preventing air traffic from making use of cloud-based data service provision. A more flexible use of external data services, considering data properties and access rights, would allow the infrastructure to be rationalised, reducing the related costs. It will enable data-sharing, foster a more dynamic airspace management and ATM service provision, allowing ATS units to improve capacity in portions of airspace where traffic demand exceeds the available capacity. Furthermore, it offers options for the contingency of operations and the resilience of ATM service provision.

Expected impact. The interoperability criteria on the flight object (i.e. sharing of flight data in a consistent, widely and easily available manner, subject to appropriate access controls) will need to have reached a sufficient level of maturity to allow all parties involved access to the data at any time during all the flight phases, from pre departure to on-block.

Additional connectivity relying on controller–pilot data-link communication is available and is considered to provide a solid alternative to the very high frequency (VHF) voice communication channels.

The establishment of a fully virtualised environment will need to be coordinated with the ATCO licencing scheme, and will therefore also be people-centric. The active inclusion of the ATCO and air traffic safety electronics personnel (ATSEP) communities in the development phase is a prerequisite for successful implementation. Close collaboration with, and input into, the EU regulatory process is required so that, when necessary, the regulations can be adapted in a timely manner to allow for deployment.

The standardisation processes conducted by the European standardisation organisations, including EUROCAE, must be launched to ensure a set of common standards.

The activities performed at European level must become a building block for the global ATM environment, hence close collaboration with the International Civil Aviation Organization (ICAO) is needed.

6. Multimodality and passenger experience. A significant portion of the planned door-to-door (D2D) journey time is taken up by the buffers needed to absorb uncertainties associated with the performance of the various modes contributing to a journey (including within the airports). Mobility providers need access to reliable planning and real-time information on

20 Urban Air Mobility is the subset of Innovative Air Mobility (IAM) operations conducted into, within or out of urban environments.Innovative Air Mobility is the safe, secure, and sustainable air mobility of passengers and cargo enabled by new generation technologies integrated into a multimodal transportation system

schedules to give more accurate forecasts of arrival and transfer times. Optimising D2D mobility for people and goods is essential in meeting citizens' expectations for increasingly seamless mobility, where they can rely on the predictability of every planned door-to-door journey and can choose how to optimise it (shortest travel time, least cost, minimal environmental impact, etc.). Considering ATM to be an integrated part of an intermodal transport system will make it possible to share data between modes and to collaborate better to optimise the performance of both the overall transport system and the D2D journey.

Expected impact. Optimised operations due to improved gate-to-gate planning contribute to the optimisation of fuel burn and, therefore, of CO_2 emissions per flight. Additional environmental benefits will come from alleviating congestion at and around airports by improving passenger flows (through predictability and single ticketing), from helping access/egress to/from airports, using environmentally friendly means, and from integrating vertiports for electric UAM vehicles.

Sharing data on air transport with travel service providers will help passengers plan intermodal journeys that include air segments. During the journey, complete integration of airports as multimodal nodes into the ATM network will enable full and seamless interoperability between the surface transport network, airports, airspace operations and Network Manager systems, contributing to increasing network resilience and the reliability and predictability of journey parameters, enhancing punctuality and passenger experience overall.

Fully integrating the most congested airports into the ATM planning process and introducing tools that allow user-driven prioritisation based on real-time multimodal passenger constraint information, monitored and shared accurately at network level, will help reduce departure delay, while improving instrument flight rules (IFR) movement numbers at these airports and, ultimately, IFR network throughput.

The data-sharing-powered network performance cockpit will enable increased predictability of traffic flows coupled with increased network flexibility and resilience. This would in turn help reduce en route congestion and ANS costs. New data-sharing standards and systems will allow new 'as a service' businesses, creating more value for aviation, within an integrated transport system.

Improved, accurate, customer-focused planning, including user-driven prioritisation, allows operators to customise and optimise every flight, balancing their individual constraints against those of the network, with a direct positive impact on additional gate-to-gate flight time, fuel burn per flight, and operational costs from congestion and disruption.

There will also be a positive impact on resilience from data-sharing, increased knowledge and integrated network crisis management processes.

Better integration of UAS, UAM and general aviation operations at airports and within terminal manoeuvring areas (TMAs) will directly contribute to increased, seamless and hassle-free mobility while enhancing operational safety. Similarly, punctual, predictable, integrated ground transport to/from the airport will reduce passenger stress and contribute to reducing stress-related accidents.

7. Aviation Green Deal. The objective of net-zero greenhouse gas emissions by 2050 set by the European Green Deal, in line with the EU's commitment to global climate action under the Paris Agreement, requires accelerating the shift to smarter and more sustainable mobility. This implies the need for aviation to intensify its efforts to reduce emissions. To this end, a set of operational measures to improve the fuel efficiency of flights will have to be put in place with the aim of enabling aircraft to fly their optimum fuel-efficient four-dimensional (4D) trajectory. At the same time, to ensure sustainable air traffic growth, it is necessary to speed up the modernisation of the air infrastructure to offer more capability and capacity, making it more resilient to future traffic demand and more adaptable through more flexible ATM procedures. Furthermore, reducing aircraft noise impacts and improving air quality will remain priorities around airports.

Expected impact. Not splitting sectors further and increasing capacity will enable the optimisation of flight trajectories, providing important fuel efficiencies and, thus, CO_2 reductions. Innovative approaches such as formation flight will bring additional fuel savings.

A high level of automation will make it possible to go beyond the current limits of sector capacity due to controller workload, which will allow optimal and environmentally friendly flight trajectories.

Automation will result in significant productivity gains, without limiting the sector or impacting controller workloads. Saving fuel for airspace users will reduce CO_2 emissions and related costs for emission allowances.

Safety levels are maintained or improved in the case of a high level of automation. The greatest benefit would be at the highest level of automation. At intermediate level, keeping the human in the loop might be delicate and would not necessarily bring the most optimum safety benefit. It is suggested to initially start automation at night, in oceanic or low-density airspace, in order to gain experience.

8. Artificial intelligence (AI) for aviation. AI is one of the main tools that will allow the current limitations in the ATM system to be overcome. A new field of opportunities arises from the general introduction of AI, enabling higher levels of automation and impacting the ATM system in different ways. AI can identify patterns in complex real-world data that human and conventional computer-assisted analyses struggle to identify; can identify events; and can provide support in decision-making, and even optimisation. Over recent years, developments and applications of AI have shown that it is a key ally in overcoming these present-day limitations, as in other domains. Tomorrow's aviation infrastructure will be more data-intensive and, thanks to the application of machine learning, deep learning and big data analytics, aviation practitioners will be able to design an ATM system that is smarter and safer, by constantly analysing and learning from the ATM ecosystem.

Expected impact. AI will enable the optimisation of aircraft trajectories, allowing a potential reduction in the aviation environmental footprint.

AI will play a fundamental role in aviation/ATM to address airspace capacity shortages, enabling dynamic configuration of the airspace and allowing dynamic spacing separation between aircrafts.

AI will enrich aviation data sets with new types of data sets unlocking air/ground AI-based applications, fostering data-sharing and building up an inclusive AI aviation/ATM partnership. This will support decision-makers, pilots, ATCOs and other stakeholders, bringing benefits in cost-efficiency by increasing ATCO productivity (reducing workload and increasing complexity capabilities).

Increasing predictability will be a key role for AI, by enabling traffic predictions and forecasts that will boost punctuality.

Safety science will also need to evolve to cope with the safety challenges posed by the introduction of machine learning.

Actual safety levels will be at least maintained using this technology.

AI will offer the possibility to stay cyber-resilient to new technologies and threats, the objective being to maintain a high level of security.

9. Civil/military interoperability and coordination. The digital transformation of the European ATM network will have an impact on both civil and military aviation and ATM operations. Care must be taken to ensure a sufficient level of civil/military interoperability and coordination, especially concerning trajectory and airspace information exchange, as well as the use of interoperable communications, navigation and surveillance (CNS) technologies. Therefore, a joint and cooperative civil–military approach to ATM modernisation would be the best choice to achieve the appropriate level of interoperability, and also to maximise synergies between civil and military R & I activities.

Expected impact.

Direct contributions to military mission effectiveness through improved collaborative decision-making in the mission planning phase, increased adherence to planned trajectories, accommodation of unpredictable and complex mission profiles, enriched surveillance and threat detection at a reasonable cost;

Indirect contributions to the European network's performance as regards safety, predictability, capacity, flight efficiency and CO_2 emissions reduction for all operational stakeholders, particularly resulting from a common civil/military approach in defining a European ATM Architecture evolution that respects the national and collective defence requirements.

The related military ambition is to execute missions as required. Achieving greater congruence between mission planning and execution leads to greater mission effectiveness and the improved predictability of 4D mission trajectories.

As a part of the Digital European Sky Programme, these flagships and the related R & I needs will be mapped with performance ambitions of the SES and further developed into candidate SESAR Solutions.

To implement the SRIA a number of further activities need to be carried that are not further detailed in this SRIA. These are the so-called transversal activities of architecting, master planning, performance management and preparation for standardisation. As part of the SESAR 3 JU programme management activities, these activities contribute to the overall framework that will make the Digital European Sky programme not just a list of disconnected projects, but a coherent programme, delivering Solutions that are developped in a consistent and coherent manner, at content level, with the direction set by the SRIA and the ambitions in the European ATM Master Plan.

In order to guarantee the development of the Digital European Sky Programme, these SESAR Solutions will have to comply with the following principles (where relevant):

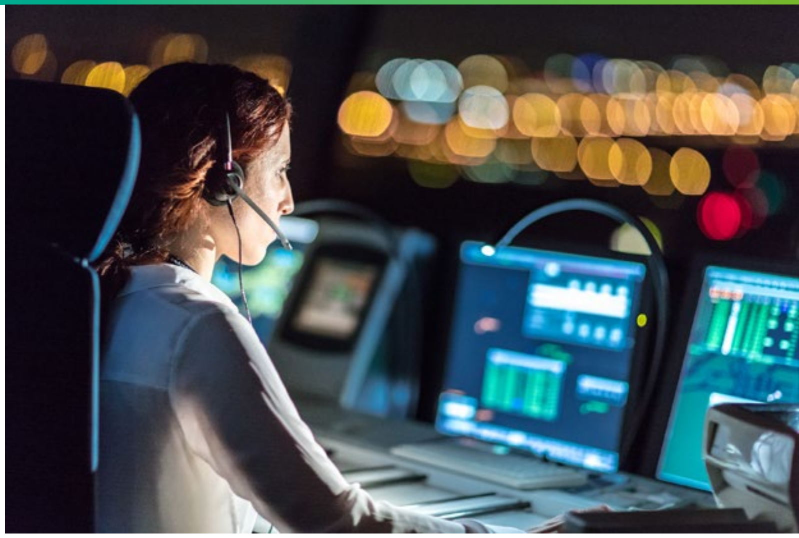
- demonstrating a high potential contribution to establishing Europe as the most environmentally friendly region in which to fly in the world;
- demonstrating a significant contribution to the realisation of the Digital European Sky vision (SESAR phase D), in particular in relation to achieving:
  - fully scalable services supported by a digital eco-system;
  - implementation of Digital European Sky target architecture and transformation to TBO;
  - highly resilient and efficient airport operations, passenger-centric, multimodality;
  - SPO, delegation of separation responsibility to systems;
  - high and full automation (level 4/5);
  - full U-space services;
- demonstrating a significant contribution to the finalisation of the SESAR phase C, as developed in SESAR 2020 (for the first Industrial Research and for Digital Sky Demonstrator calls only);
- demonstrating the need for finding a common solution across the European network (vs local), with a clear need for standardisation;
- demonstrating a clear breakthrough potential (vs business as usual) in the medium (2025) and long (2028–2029) terms.

2.2.3. Extended release strategy

The Extended Release Strategy (ERS) provides at any time an overview of the SESAR 3 JU programme planned deliveries across the research & innovation pipeline. By setting the target maturity levels for the content under development by the SESAR projects e.g. SESAR solutions and their associated target exit TRL, the ERS drives the top-down approach connecting the strategic level of the ATM Master Plan, SRIA and MAWP to the working level of the Programme. In particular the ERS identifies when the SESAR Solutions need to achieve end of TRL-6, -7 or -8 maturity in order to meet the Master Plan expectations.

The Extended Release Strategy aims at:

- Steering the SESAR 3 JU R&I work to achieve the ATM Master Plan (e.g. vision phase D and also remaining work to complete Phase C Key R&D solutions) and performance ambitions by planning the target maturity levels that the SESAR projects shall aim at for the content under their scope (i.e. SESAR solutions);
- Monitoring the progress of SESAR 3 JU projects towards the maturity targets and identifying any deviation leading to corrective action;
- Ensuring the yearly planning and reporting of the SESAR 3 JU projects deliveries, via the annual Release Plan and Report;



- Supporting the definition of the Calls content in identifying the SESAR Solutions still requiring further development and validation.

The Extended Release Strategy is updated on a yearly basis. This update represents an opportunity to re-align the strategic view with the development and validation layer e.g. baselining the changes issued during project reviews (supported by SESAR Solution Maturity assessment), SESAR Solution maturity gates, and identify potential significant impacts on the SRIA.

2.2.4. Calls for proposals

2.2.4.1. Sequence of calls for proposals

The Digital European Sky Programme is delivered using range of instruments under Horizon Europe for the Exploratory and Industrial Research activities while the Digital Sky Demonstrators are secured using the CEF financing framework.

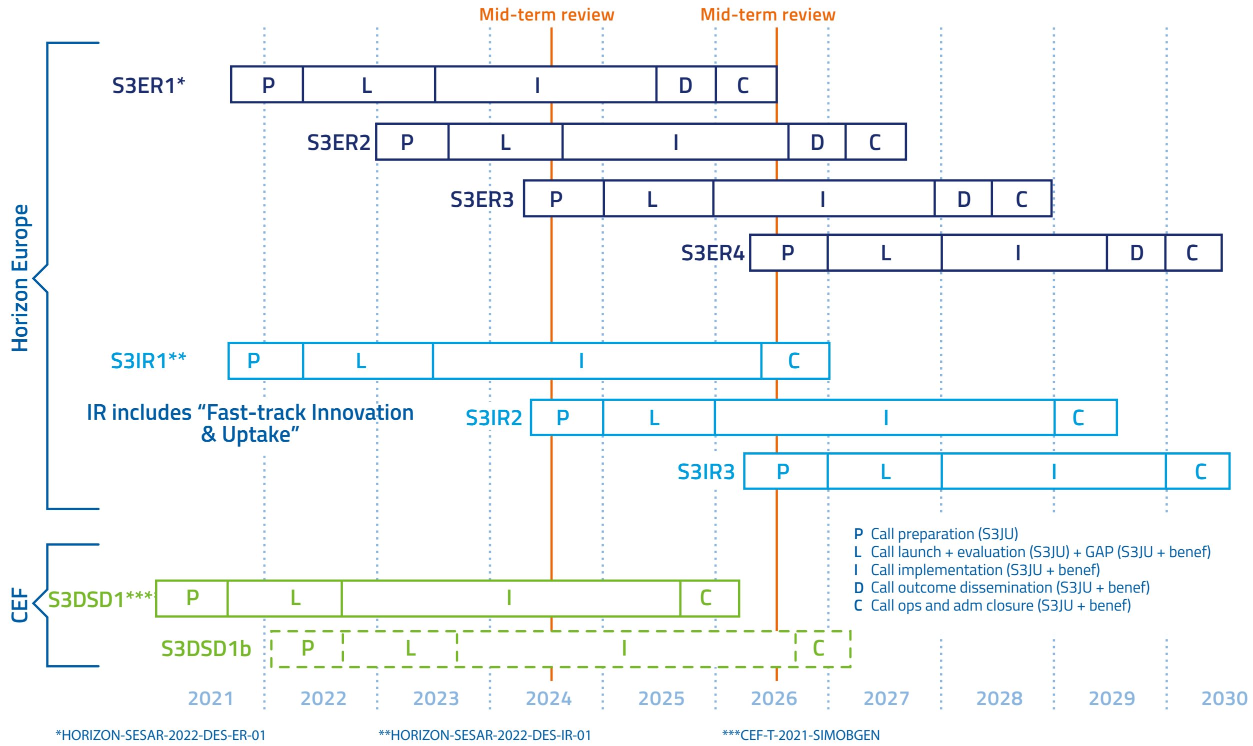
There will be three types of calls for proposals covering three R & I phases defined in subparagraph 2.2.1.2 'R & I activities within the innovation pipeline': (1) Exploratory Research calls with Horizon Europe funding; (2) Industrial Research and Validation, also covering fast-track innovation and uptake with Horizon Europe funding; and (3) Digital Sky Demonstrators with CEF funding managed by CINEA in close cooperation with the SESAR 3 JU. The funding allocation per call is outlined in subparagraph 2.2.3.3. 'Budget allocation (European Union contribution) to calls for proposals', below.

Four calls for proposals are planned for the **Exploratory Research** phase. The first call for Exploratory Research is to be published in early Q2 2022, to allow the launch into execution of the first exploratory research projects in the course of Q2 2023. The subsequent calls will be scheduled in order to complete the proposed exploratory research content described in this document. The duration of the exploratory research projects is planned for a duration of 2.5 years including a 6-month period allowing them at the end of their life cycle to carry out communication, dissemination and exploitation activities (as recommended by the SESAR 2020 Scientific Committee). The duration of the projects under the last exploratory research call will be limited to a 2-year period to secure the closure procedure of the Digital European Sky Programme and SESAR 3 JU by the end of 2031.

Three calls for proposals are planned for the **Industrial Research and Validation** phase, also covering Fast-track Innovation and Uptake. The first industrial research call is also planned to be published in early Q2 2022, allowing the launch into execution of the first industrial research projects in the course of Q2 2023. The first industrial research call will be synchronised with the first exploratory research call in order to optimise their management (e.g. call publication, evaluation and grant agreement preparation activities) and the resources allocation. Three Waves of calls of proposals will be organised, each planned to make significant steps towards the achievement of the specific objectives of the SESAR 3 JU, and performed in a manner similar to that of the SESAR 2020 programme. This will also support ongoing feedback to the European ATM Master Plan, standards development and identification of needs for future regulation. The industrial research projects' duration is planned for a 3-year period except for the last industrial research call, which will limit its duration to a 2-year period to secure the closure procedure of the Digital European Sky programme and the SESAR 3 JU by the end of 2031.

For **Digital Sky Demonstrators**, a first call has been launched by CINEA at the end of quarter 3 (Q3) of 2021. Subject to the signature of a contribution agreement between the SESAR 3 JU and the Commission and of a specific working arrangement established between the SESAR 3 JU and CINEA, the SESAR 3 JU will ensure the strategic orientation of this call for proposals and support to the management of resulting grants through technical expertise during the call evaluation and grant management phases; the activities carried out by the SESAR 3 JU in this cooperation with CINEA are described in subparagraph 2.2.3.2 'SESAR 3 JU's contribution to Digital Sky Demonstrators', below. A second call for proposals for Digital Sky Demonstrators is planned to be launched in Q3 of 2022, subject to confirmation of the working arrangements between the SESAR 3 JU and CINEA. SJU will maintain a list of candidates for DSD subject to availability of CEF funding with the view of launching from 2024.

FIGURE 7: THE DIGITAL EUROPEAN SKY CALLS SEQUENCE



The high-level planning is shown in Figure 7.

The calls sequence is taking into consideration the need to ensure the R & I pipeline in feeding the new calls with previous calls' results. Particular care must be taken to secure bridging to Digital European Sky from the results of SESAR 2020. The closure of the SESAR 2020 programme will focus on managing the timely completion of the remaining work, with particular emphasis on the delivery of Release 12 results and the proper performance of the technical closure processes of all relevant projects by June 2023. An additional period of six months will be required to perform the financial closure of the projects as defined by Horizon 2020.

The definition phase of the Digital European Sky Programme is carried out in parallel with the definition of the last SESAR 2020 Release 12 content and will be finalised when Release 12 is in its early execution phase. This parallel approach enables the SESAR 3 JU and the candidate members to keep an accurate view of the evolution of the maturity of the SESAR solutions and to reflect it in regular updates of the Release Strategy. SESAR Solutions considered as not ready at the end of SESAR 2020 would be included in the Digital European Sky projects' definition in order to further complete their validation.

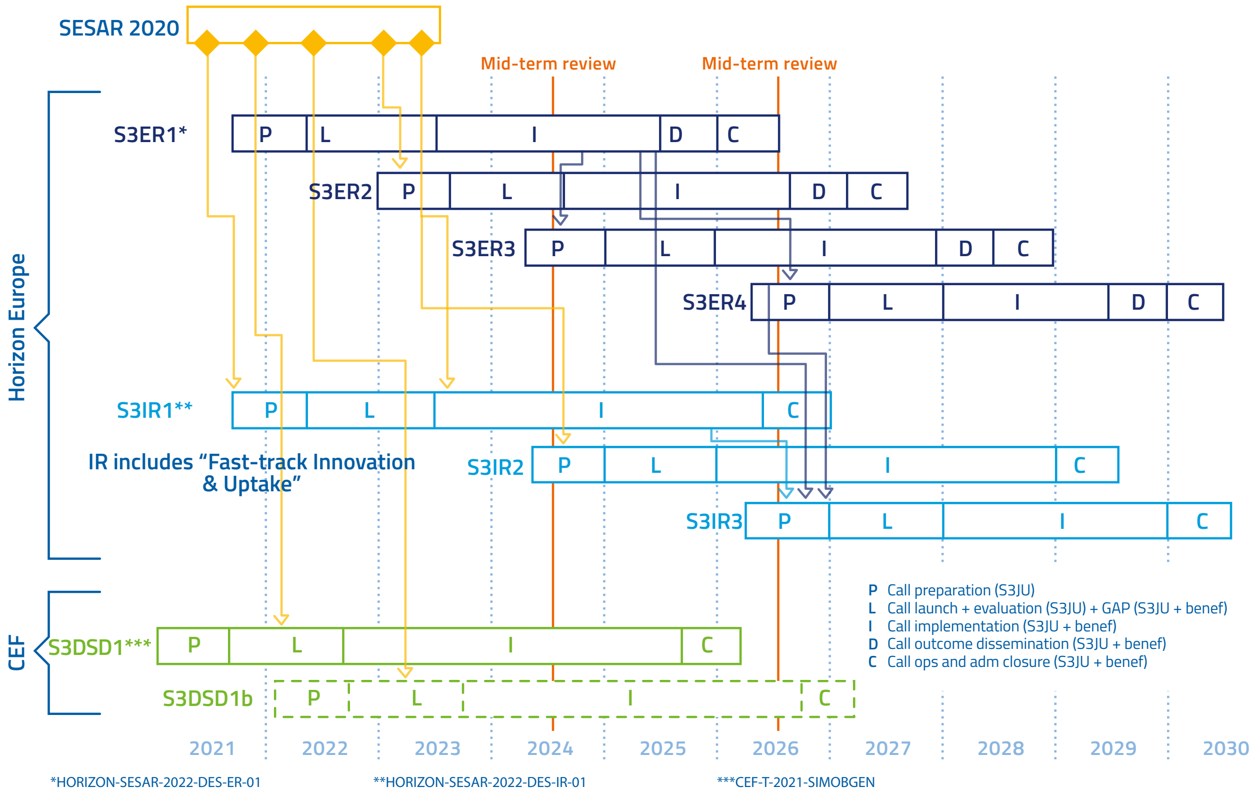
To capture and propagate this knowledge with accuracy, the programme closure phase will also address content and material developed in SESAR 2020, ensuring that it is:

- made available for local deployment by a wide range of ATM stakeholders and for coordinated deployment facilitated by the SESAR Deployment Manager, as described in their deployment programme;
- transferred to the Digital European Sky Programme for further development or;
- archived in line with the legal requirements.

The update campaign of the Master Plan in 2019, in parallel with the definition of the Wave 2 and Wave 3 calls' preparation, offered a good opportunity to the SESAR JU to already consider a first mapping between the SESAR 2020 programme, the Essential Operational Changes and the phased evolution of the high-level architecture, as defined in the 2020 edition of the Master Plan endorsed by the Administrative Board of the SESAR JU in December 2019. It was also a way to already prepare the bridge between the Digital European Sky programme content and the final deliveries of the SESAR 2020 programme.

A consistent transition between the two programmes has therefore been ensured by guaranteeing the consistency between the main drivers, such as the Release Strategy, the Digital European Sky Programme and the ATM Master Plan 2020. In addition to

FIGURE 8: INTEGRATION AND INTERRELATIONS BETWEEN THE DIGITAL EUROPEAN SKY CALLS AND THE SESAR 2020 PROGRAMME



this consistency, clear reference to SESAR 2020 deliverables will be made in the description of the Digital European Sky projects, when required. The aim is to ensure that the Digital European Sky programme will start building on the foundation resulting from SESAR 2020 validation activities, where required.

In addition to the transfer of outcomes from the SESAR 2020 programme to the Digital European Sky Programme, the optimisation of the sequence of calls also guarantees that the outcomes stemming from an R & I pillar will be considered as further inputs in the preparation and the technical specifications for calls in other pillars.

Figure 8 presents all the dependencies that can be identified across the different pillars and calls, demonstrating the possible transfer of results from a call to another:

2.2.4.2. The contribution of the SESAR 3 JU to Digital Sky Demonstrators

Digital Sky Demonstrators, funded under the CEF, are subject to a specific working arrangement between the SESAR 3 JU and CINEA.

In this working arrangement, CINEA is responsible for the management of the call(s) for proposals, with strategic orientation, technical input and support for the SESAR 3 JU as follows:

- the technical specifications developed by the SESAR 3 JU, in accordance with the multiannual work programme, are the technical reference in the call(s);
- the SESAR 3 JU develops execution guidance for the management of the projects supported by the grant agreements, which form part of the call material;
- the SESAR 3 JU contributes to communication activities related to the call(s) for proposals, in particular a specific Digital Sky Demonstrator call information day (joint with CINEA);
- the SESAR 3 JU contributes to the technical evaluation to allow its scoring of proposals and its moderation role in evaluation panels;
- the SESAR 3 JU contributes to the final selection of the proposals through the ranking list at the end of the technical evaluation.

In relation to grants resulting from the calls for proposals, CINEA is responsible for the management of a grant agreement's contractual, administrative and financial aspects, while the SESAR 3 JU is responsible for all content- / technical-related matters, namely:

- the (technical) project kick-off meeting;
- deliverable templates defined by the SESAR 3 JU and applied by projects to guarantee that the outputs are aligned with the Digital European Sky programme;
- regular review/coordination of draft deliverables (through a collaborative platform);
- participation in project follow-up meetings (e.g. PMB, usual SESAR 3 JU–project coordination);
- monitoring of project schedule;
- set-up of the exit maturity gates;
- control of project contribution to EASA and EUROCAE;
- monitoring of project contributions to communication, dissemination and exploitation activities;
- providing technical input and support to CINEA in relation to all points above and their impacts on contractual and financial aspects.

2.2.4.3. Budget allocation (European Union contribution) to calls for proposals

The budget allocation to calls for proposals (EU contribution) is based on the EU budget assumptions set out in Section 4. 'Financial resources and planned expenditure', below. This allocation aims to combine several factors:

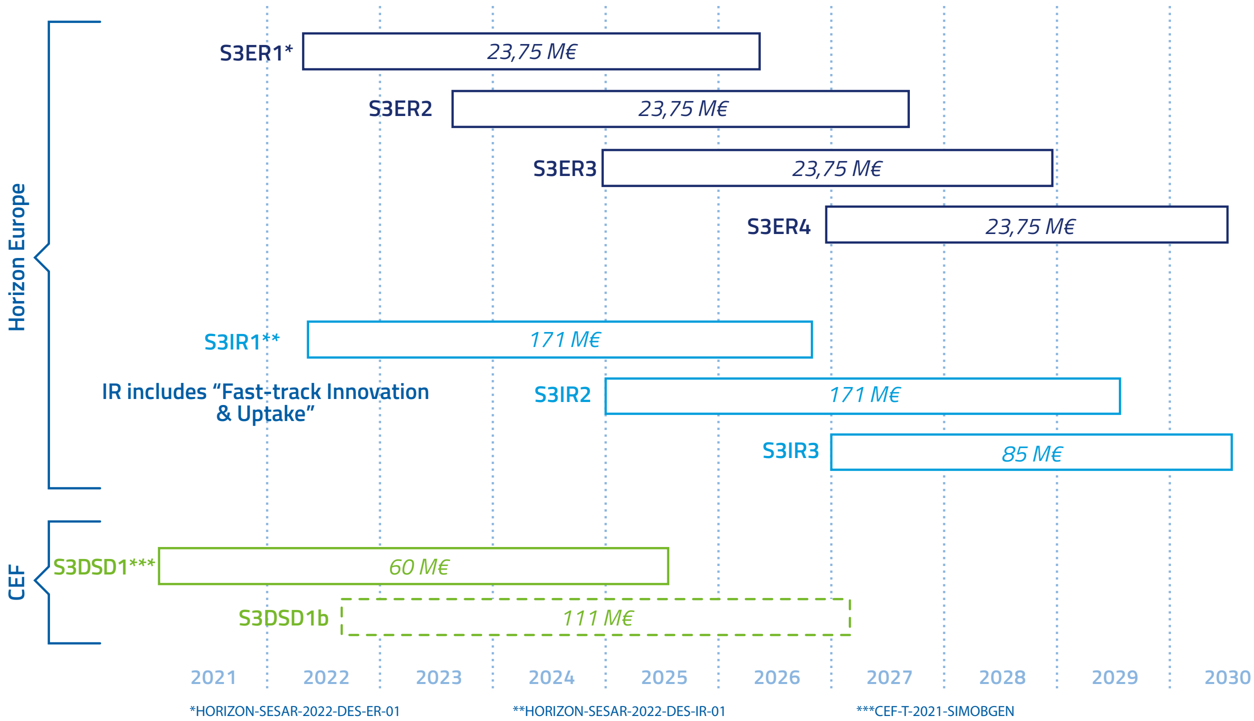
- the timing of the delegation of funds from the EU,
- the need to launch Digital European Sky Programme activities as early as possible after the adoption of the SESAR 3 JU basic act,
- the need to secure continuity of operations with the SESAR 2020 programme where relevant,
- the expected investment capacity of the industry.

The total amount dedicated to the Exploratory Research (ER) grants, fully funded under Horizon Europe, is EUR 95 million. It will be evenly divided into four calls for proposals of EUR 23.75 million each.

As for the total amount dedicated to Industrial Research (IR, also covering Fast-Track Innovation and Uptake) calls, that is EUR 427 million fully funded under Horizon Europe, it could be used in two first calls of EUR 171 million each (Wave 1 and Wave 2), while a third call could be organised later on with the remaining EUR 85 million and the unused appropriation from the two first calls. For each call, it is expected that 70 % of the budget would be allocated to traditional IR activities, and 30 % to Fast-Track Innovation and Uptake activities.

The amount dedicated to the Digital Sky Demonstrators will depend on the technical assistance agreement with the European Commission for the use of CEF funds. A first call for proposals, managed by CINEA in cooperation with the SESAR 3 JU, was launched in Q3 of 2021, with a total value of EUR 60 million, and is planned to be followed by a second call for proposals in Q3 of 2022, with a total value of EUR 111 million.

FIGURE 9: **DIGITAL EUROPEAN SKY CALL SEQUENCE AND INITIAL BUDGET ALLOCATION PER CALL (EU CONTRIBUTION)**



The following should be noted:

- as a principle, unused funds under one particular call should be allocated to a subsequent call within the same R & I phase (namely Exploratory Research, Industrial Research, Fast-Track Innovation and Uptake or Digital Sky Demonstrators);
- the preparation of the working arrangement defining the mandate of the SESAR 3 JU for the use of CEF funds managed by CINEA should cover the description of the entrusted tasks, the estimated budget and the duration.

The SESAR 3 JU financial resources are identified in Section 4, 'Financial resources and planned expenditure', below.

2.3. SESAR outreach

In accordance with the general and specific objectives laid down in the basic act, the SESAR 3 JU will engage in a number of operational activities aimed at developing close cooperation and coordination with other European partnerships; seeking synergies at European, national and regional levels; promoting collaboration across the aviation ecosystem through liaising with an extensive range of stakeholders; and strengthening international cooperation with the goal of ensuring global interoperability. The SESAR 3 JU will also seek to promote and support the delivery of the Digital European Sky through a wide range of communications activities, and will provide technical support to the European Commission to assist it in development of policies relating to ATM modernisation.

2.3.1. Synergies

2.3.1.1. Maximising synergies across Horizon Europe

The SESAR 3 JU will put in place measures to maximise its impact using all possible synergies with other European partnerships and related national activities. Beyond the involvement in the overall coordination of Horizon Europe, the SESAR 3 JU will, in particular, focus on capturing synergies across the following two clusters.

- **Synergies within the "Climate, Energy and Mobility" cluster.** In this thread, the SESAR 3 JU will reach out to other mobility JUs with the aim of building consolidated roadmaps and action plans for climate neutral mobility solutions. This

will also address common sectorial issues such as multimodality transport, automated vehicles and the decarbonisation of the sector. In particular, a specific coordination with the European Partnership for Clean Aviation is believed to be essential for the aviation sector.

- **Synergies with the "Digital, Industry and Space" cluster.** Considering that the digital transformation of aviation is at the core of the SESAR 3 JU's goals, it strongly echoes the ambition of the "Digital, Industry and Space" cluster. It is in many ways complementing this cluster by addressing aviation-critical applications. Therefore, it is essential to put in place synergies with all relevant digital initiatives outside the "Climate, Energy and Mobility" cluster. For example AI, cybersecurity and high-performance computing are cross-sectorial issues that require deep coordination, especially for the development of use cases and the application of European standards. In addition, the partnership will contribute to the achievement of the European space policy. According to the European ATM Master Plan, satellite CNS services are considered essential enablers of the Digital European Sky. Therefore, the partnership will build on the achievements of SESAR 2020 in the space domain to further engage the space actors in the innovation ecosystem.

2.3.1.2. A coordinated action with the European Partnership for Clean Aviation

The Clean Aviation and SESAR 3 JUs will play an essential role in successfully driving the aviation sector to achieve environmental and mobility goals set out for Europe's aviation, while contributing to the objectives of the European Commission. These goals will be attained through the R & D of key innovative technologies for the decarbonisation / energy transition and digital transformation of the aviation sector.

Opportunities will be actively sought for running joint demonstration activities. This would enable the two programmes to show, in practice, the complementarities and synergies between them. It could also allow the programmes to evaluate the combined benefits and impact of particular solutions, in particular, for example, the measurement of the aggregated effect of green operations and green aircraft on the achievement of the overall decarbonisation goal. In order to facilitate joint demonstration activities, there will need to be a sufficiently flexible funding framework in place.

A first set of potential areas to demonstrate the synergy effects has been identified (this list is not exhaustive):

- combined simulations,
- performance and impact assessment,
- autonomous operations,
- airport infrastructure for new vehicles.

2.3.1.3. Synergies with CINEA

As part of the Digital European Sky Programme, the implementation of Digital Sky Demonstrators funded under the CEF programme requires a strong cooperation with CINEA, as presented in subparagraph 2.2.3.2., 'SESAR 3 JU's contribution to Digital Sky Demonstrators', above.

Synergies between civil, defence and space industries

The "EU Action Plan on Synergies between civil, defence and space industries"[21] to further enhance Europe's technological edge and support its industrial base states that "several EU-funded initiatives lay the ground for cross-sectoral synergies, including SESAR (Single European Sky Air traffic management Research)".

2.3.1.4. Coherence and synergies in relation to major national (sectorial) policies, programmes and activities

To help repair the economic and social damage caused by the COVID-19 pandemic to the aviation sector, the SESAR 3 JU will exploit all possible synergies in relation to major national (sectorial) policies, programmes and activities (such as those that will be part of the EU stimulus package called Recovery and Resilience Facility to ensure maximum levels of complementarity and impact). It will aim to leverage local investments and complement the R & I needs by looking at the wider European goals and applications.

The SESAR 3 JU will explore opportunities for coordination with national and regional initiatives and consult widely on that also through the newly established States' Representatives Group

The synergies identified above will be subject of specific activities defined in future Work Programmes of the SESAR 3 JU.

21 https://ec.europa.eu/info/files/action-plan-synergies-between-civil-defence-and-space-industries_en

2.3.2. Stakeholder engagement

The SESAR 3 JU is responsible for securing support and buy-in from all stakeholders for the definition (European ATM Master Plan) and development of SESAR technologies and procedures (SESAR solutions). This requires continued and extensive outreach in the form of communications and external relations (including international affairs), supported by the core SESAR membership, and cooperative arrangements with specific stakeholder groups.

The SESAR 3 JU's outreach work will target and involve a wide range of SESAR 3 JU member and stakeholder organisations. This outreach aims to secure the involvement of stakeholders in the SESAR 3 JU's R & I activities, including in support of validating SESAR solutions, as well as to ensure close coordination and, where appropriate, alignment with activities delivered by other organisations, but which are of strategic importance to the success of the SESAR project, such as standardisation.

2.3.2.1. Institutional stakeholders

The SESAR 3 JU will maintain close relations with its key institutional stakeholders, such as the European Commission, the European Parliament and the European Council, along with the European Organisation for the Safety of Air Navigation (Eurocontrol), in order to ensure that its activities are aligned with and take into account developments in the EU's policy towards ATM. It will also establish appropriate cooperation and coordination with the following organisations, including through formal cooperative arrangements when appropriate.

- **EASA** – to secure close collaboration with EASA in order to ensure an early exchange of knowledge on new technologies being developed, thereby facilitating the certification and regulatory processes of resulting products and services, and ultimately accelerating market uptake of SESAR solutions. The arrangements will allow EASA to contribute expertise in support of key SESAR project activities and, at the same time, allow the SESAR 3 JU to provide support to EASA in European and international activities that relate to securing the necessary safety, security and regulatory arrangements.
- **European Defence Agency** – to secure support and buy-in from the military community (in their roles as air navigation service providers (ANSPs), airport operators, airspace users and regulators) in relation to SESAR 3 JU activities and the ATM Master Plan. In particular, areas of common interest include the ATM Master Plan, regulations, space-based systems, the integration of unmanned aerial systems, cybersecurity threats and vulnerabilities of ATM, and the development of aviation/ATM standards.

- **European Space Agency** – to focus on strategic cooperation to coordinate roadmaps, specifically in relation to the integrated CNS strategy defined in the ATM Master Plan, defining the role of satellite communications as an element of importance for the future enabling CNS infrastructure for ATM.
- **EU Agency for the Space Programme** – to ensure coordination in relation to the role of the European Geostationary Navigation Overlay Service (EGNOS) and Galileo in the future multi-frequency, multi-constellation global navigation satellite system (GNSS) system.

2.3.2.2. Industry stakeholders

The SESAR 3 JU aims to foster strong ties with key European stakeholder groups, including, in particular, the following.

- **SESAR deployment**. The SESAR 3 JU will cooperate with the entity established to coordinate the tasks of the SESAR deployment phase to ensure the necessary connections between SESAR development and deployment activities. ;
- **Advisory Council for Aviation Research and Innovation in Europe (ACARE)**. The SESAR 3 JU will participate in the advisory council to ensure the appropriate representation of ATM in the European strategic R & I agenda, and to secure the link with Flightpath 2050.
- **Standardisation bodies**. The contribution of the SESAR 3 JU to the development of European standards is of key importance in helping accelerate market uptake of SESAR Solutions. The SESAR 3 JU will seek to intensify its engagement with relevant Standards Development Organisations and in particular EUROCAE through strengthening the pre-existing Memorandum

of Understanding reflecting the new regulatory obligations of the JU. The SESAR 3 JU will continue to participate actively in the EUROCAE Council and the Technical Advisory Committee, as well as the European ATM Standards Coordination Group and the European UAS Standards Coordination Group. The aim is to secure close collaboration between the SESAR 3 JU members and the availability of SESAR material in support of standardisation, and to enable SESAR material to be used to plan the effective development of standards to support European regulation, international standardisation and delivery of the ATM Master Plan and the ICAO Global Air Navigation Plan (GANP).

- **Air navigation service providers**. The SESAR 3 JU will work closely with CANSO in order to ensure the broadest possible awareness of the activities of the SESAR 3 JU and to secure engagement and buy-in from air navigation service providers, including those outside the membership of the SESAR 3 JU.
- **Professional staff organisations**. The SESAR 3 JU will secure the support of the different professional staff associations to provide operational and technical knowledge of direct relevance to the successful delivery of SESAR results and solutions. This will also serve to enhance the buy-in of front-end users in relation to ATM modernisation and SESAR solutions.
- **Civil and military airspace users.** The SESAR 3 JU will continue to reach out to airspace user organisations to secure awareness of and commitment to its work and activities, including to secure, when appropriate, their advice for programme-related activities.
- **European airports**. The SESAR 3 JU will work closely with European airports and the Airports Council International on airport-related activities in its work programme in order to secure their active engagement and to raise awareness of SESAR among airport partners, including through events such as roadshows and conferences.
- **New entrants**. New innovative airspace users and organisations in the field of unmanned traffic management (UTM) / U-space, unmanned aerial systems and HAO will be approached based on relevant EU strategies and on a case-by-case basis to find the most efficient mechanism of cooperation for the benefit of SESAR 3 JU tasks and activities.
- **SMEs and start-ups**. The SESAR 3 JU will seek opportunities to reach out to small and medium-sized enterprises and start-ups in order to associate them with its activities and thereby help stimulate and scale-up the research and innovation network. This will include exploring possibilities to put in place cooperative arrangements to inform and involve this community, for example with the European Aerospace Cluster sponsored by DG GROW and the European Start-Up Prize for Mobility under the patronage of the European Parliament.

2.3.3. Cooperation with third countries and international organisations

The SESAR 3 JU's international cooperation activities will be conducted in close coordination with the European Commission to ensure consistency and alignment with the EU's broader aviation strategy, in particular its external affairs dimension.

The SESAR 3 JU will conduct outreach activities with international partners pursuant to its strategy for cooperation with third countries and/or international organisations. The principal objectives of this strategy are threefold:

- to secure global leadership for SESAR in the context of the ICAO;
- to ensure global interoperability and harmonisation based on SESAR solutions;
- to promote and support the competitiveness of the European aviation and ATM industry.

2.3.3.1. Cooperation with the International Civil Aviation Organization

The ICAO is the global body responsible for developing international civil aviation standards and recommended practices and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector. A key objective of the SESAR 3 JU's international engagement is to ensure alignment between its priorities and those established at ICAO level. It is particularly important to ensure that the European ATM Master Plan and industry standardisation initiatives remain aligned with the relevant ICAO provisions and their future evolution. For this reason, the SESAR 3 JU will work closely with the European Commission and other European institutions and partners, notably EASA and Eurocontrol, to promote European positions and global interoperability. The SESAR 3 JU will participate in European ICAO coordination meetings, chaired by the European Commission, as a means to define European priorities and to plan accompanying actions and inputs to the ICAO. The SESAR 3 JU will also participate in the broader European Safety and Air Navigation Coordination Group, which ensures coordination with the 44 European Civil Aviation Conference states.

In 2022–2023, the SESAR 3 JU's ICAO-related activities will involve engagement on the future evolution of the

GANP and the aviation system block upgrades through participation in relevant groups such as the ICAO GANP Study Group. A particular milestone over the period will be the 41st ICAO Assembly, which will take place in 2022. The SESAR 3 JU will also seek to work closely with the ICAO as it develops policies in strategically important domains, such as integrated CNS, drones, HAO and environmental targets.

By continuing to engage closely with such activities, the SESAR 3 JU is able to ensure that policies, standards and provisions being established at the global level are interoperable and harmonised with those being developed through the SESAR R & I pipeline, recognising that this is a vital prerequisite for a safe, secure, efficient and sustainable global ATM system. This, in turn, will help maintain and further strengthen the SESAR 3 JU's position as a global leader in aviation and ATM modernisation, which also serves to promote the competitiveness and global market shares of the European aviation and ATM industry.

2.3.3.2. Cooperation with international partners

In addition to its direct participation and involvement in ICAO activities, the SESAR 3 JU will cooperate with a number of key international partners. The JU has cooperated since 2011 with the US Federal Aviation Administration / next-generation air transportation system (NextGen) programme under the EU–US Memorandum of Cooperation on ATM modernisation, civil aviation R & I and global interoperability. The Federal Aviation Administration's NextGen programme and SESAR are the two largest ATM modernisation initiatives in the world. As such, it is essential that the two programmes are closely aligned to ensure that global interoperability and harmonisation can be maintained, not only for the present but for the future too. Maintaining regular dialogue across a range of topics and domains allows the two sides to identify any risks, issues or opportunities that may arise in relation to global interoperability.

The SESAR 3 JU will also secure cooperation with a number of other key international partners through a range of instruments, building on cooperative arrangements established previously by the SESAR JU, for example with Singapore, Qatar, the United Arab Emirates and Georgia, and seeking opportunities for new cooperative arrangements when these can add value consistent with the EU's broader external aviation policy. To this end, the SESAR 3 JU will work in close coordination with the European Commission. The SESAR 3 JU will also work closely in support of EASA on the ATM-related elements of EU technical cooperation projects with third countries and regions. Conducted within the framework of the EU's external aviation policy, these projects cover the sharing of lessons learnt, knowledge and expertise, and cooperation activities related to ATM modernisation towards ICAO.

2.3.4. Communications

Communications play an integral role in building trust, securing buy-in and maintaining momentum for the SESAR 3 JU's R & I activities. It is also key for accelerating innovation and implementation of SESAR Solutions. Table 4 provides an overview of the SESAR 3 JU communications' objectives, their corresponding actions, audiences and key messages.

For full details of the planned approach, activities and channels, please see the SESAR 3 JU communications strategy (2021–2026).

TABLE 4: OVERVIEW OF THE SESAR 3 JU COMMUNICATIONS' OBJECTIVES, ACTIONS, AUDIENCES AND KEY MESSAGES

Objectives	Actions	Target audiences	Messages
Promote the Digital European Sky vision	Ensure programme coherence – enable a process to ensure projects promote their objectives and results as part of the overall Digital European Sky programme and in line with Horizon Europe obligations Showcase solutions – illustrate that the digital European sky programme is developing solutions that can deliver tangible benefits to aviation, the economy and society	SESAR 3 JU community	The SESAR 3 JU takes a holistic look at ATM modernisation, ensuring coherency and synergies between solutions, with a view to delivering the Digital European Sky.
Promote the role of the SESAR 3 JU partnership in creating added value	Deliver value for money as a coordinated R & I ecosystem under a partnership – showcase the role of partnership as a key to ensuring a coherent R & I programme fulfilling industries' performance needs	Policymakers / decision-makers	The SESAR 3 JU as a public–private partnership is the most effective and cost-efficient instrument to deliver an integrated and modernised R & I ecosystem for ATM within Horizon Europe. It offers the best means to build consensus and coordinate stakeholders, pooling a critical mass of resources and expertise
	Enable global interoperability – promote SESAR solutions within the ICAO and third countries to ensure global interoperability, to facilitate EU exports and to gain a competitive edge internationally	Stakeholders beyond SESAR 3 JU	The SESAR 3 JU cooperates internationally to enhance global harmonisation and promote EU innovation and competitiveness
	Promote new talent – embrace disruptive technologies and unlock change by supporting and encouraging new talent entering the ATM/aviation ecosystem	Policymakers / decision-makers	The SESAR 3 JU extends the partnership to academia, small and medium-sized enterprises and start-ups to consolidate and enrich the R & I network of talent

Objectives	Actions	Target audiences	Messages
Promote SESAR R & I as an integral part of the EU's and industry's efforts to become economically and environmentally sustainable in the long term	Ensure alignment with European policy – support the delivery of EU initiatives on mobility, digitalisation and sustainability	Policymakers / decision-makers	The SESAR 3 JU supports the delivery of the Digital European Sky. It is a key element of several EU policy agendas: the sustainable and smart mobility strategy (1), the European Green Deal (2), and the 'Europe fit for the digital age' initiative (3)
	Contribute to societal needs – promote the knock-on benefits that SESAR R & I will bring to passengers and citizens	General public	The SESAR 3 JU supports improvements to ATM that have knock-on benefits for EU citizens – supporting the EU's economic growth, reducing environmental impact and improving passenger experience through enhanced transport connectivity and multimodality
	Explain R & I life cycle ('innovation pipeline') – illustrate how the SESAR approach helps accelerate innovative ideas from inception to implementation through a range of R & I instruments	SESAR 3 JU community	The SESAR 3 JU promotes research excellence with a focus on transforming initial concepts into tangible solutions for market uptake, including in SESAR 3 JU the new Digital Sky Demonstrators supportingsupport of early movers
	Boost performance and respond to challenges – showcase how R & I can adapt to evolving trends and challenges, and its role in meeting performance ambitions	SESAR 3 JU community	The SESAR 3 JU delivers solutions capable of boosting the performance of ATM/ aviation. The solutions respond to evolving challenges, with a strong emphasis on sustainability and accommodating new airspace users
Strengthen internal communications to SESAR 3 JU staff	Foster staff engagement and commitment to the SESAR 3 JU values and objectives – nurture a spirit of belonging to the organisation and support SESAR 3 JU staff in becoming brand ambassadors for the Digital European Sky Keep staff up to date on the key priorities and activities of the SESAR 3 JU – make use of communications channels to inform staff of the latest developments/achievements of the partnership	SESAR 3 JU staff	The SESAR 3 JU is an open and inclusive partnership that values its staff and their well-being and that fosters their active contribution to delivering the Digital European Sky

1 https://ec.europa.eu/transport/themes/mobilitystrategy_en
2 https://ec.europa.eu/commission/presscorner/detail/en/fs_19_6714
3 https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age_en

2.3.5. Data and dissemination

2.3.5.1. Dissemination of programme results

The SESAR 3 JU will systematically collate data from completed and ongoing projects with the aim of obtaining a comprehensive overview of the progress achieved in each financed project against the targets outlined in the SESAR 3 JU's multiannual work programme. Such data collection will enable a holistic view of the Digital European Sky programme activities and their impact.

Data will include output from projects, such as standardisation material, publications and patents, and will be made available on the SESAR 3 JU's website (via either uploaded documents or links to relevant websites) and through direct dissemination of material to the appropriate bodies in support of the preparation for deployment. In addition, the SESAR 3 JU will continue to publish and promulgate SESAR solutions once they are available and validated through the release process.

The Digital European Sky programme will comply with all provisions of the Horizon Europe programme related to dissemination, set forth in Title II of the Horizon Europe regulation ([22]), in particular its Article 39, and the Horizon Europe work programme for 2021–2022, annex 13, General Annexes, Section G ([23]). This involves monitoring the dissemination activities of beneficiaries to ensure that they provide (digital or physical) access to data or other results needed to validate the conclusions of scientific publications, to the extent that their legitimate interests or constraints are safeguarded (and unless they already provided the (open) access at publication).

As an exception, if providing open access would be against the beneficiaries' legitimate interests, the beneficiaries must grant non-exclusive licences, on fair and reasonable conditions, to legal entities that need the research output to address a public emergency. These legal entities must commit to rapidly and broadly exploiting the resulting products and services on fair and reasonable conditions. This exception is limited to 4 years after the end of the action.

2.3.5.2. SESAR Digital Academy

The vision of the SESAR Digital Academy is to become a recognised learning initiative supporting Europe's future aviation and ATM workforce. The mission is to nurture Europe's brightest minds; to advance learning, scientific excellence and innovation in aviation and ATM; to promote student mobility and a whole spectrum of learning opportunities, from fundamental research to industry-focused applied research; and to enhance the knowledge, skills and employability of aviation professionals.

The SESAR Digital Academy seeks to bring together, under one umbrella, SESAR exploratory research activities and outreach, relating to education and training, as well as professional learning opportunities offered by research centres, universities, industry partners and other entities within the ATM/aviation domain.

sesar DIGITAL ACADEMY

2.3.6. Policy support to the European Commission

The SESAR 3 JU will provide technical input to the European Commission as requested in order to assist it with aviation policymaking, for example assisting in the preparation of technical documents supporting the common projects established under

[22] Regulation (EU) No 2021/695 of the European Parliament and of the Council of 28 April 2021 establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, and repealing Regulations (EU) No 1290/2013 and (EU) No 1291/2013.

[23] European Commission Decision C(2021)1940 of 31 March 2021.

the SES regulation ([24]), conducting technical studies or supporting regulatory activities. It will also ensure the stewardship of the European ATM Master Plan endorsed by Council Decision 2009/320/EC, including monitoring, reporting and updating the European ATM Master Plan.

2.4. The strategic areas of operation of the SESAR 3 Joint Undertaking

To achieve the objectives set out in the previous sections, the SESAR 3 JU will follow five strategic areas of operation, each constituting a strategic objective of the SESAR 3 JU from 2021 to 2031.

- Strategic area of operation **1 – Provide strategic steering to the Digital European Sky programme**. The SESAR 3 JU will continue to provide strategic steering to the SESAR R & I programme and to contribute to the implementation of the EU Mobility Strategy, in particular through the links with the SES policy framework, by proposing when required updates to the European ATM Master Plan and monitoring its execution, ensuring a strong connection between development and deployment activities.
- Strategic area of operation **2 – Deliver exploratory research**. Within the pipeline for innovation (see Figure 5 in paragraph 2.2.1., 'The SESAR innovation pipeline'), the first phase concerns ER, further categorised into the elements/projects that deal with relevant fundamental scientific subjects (excellent science and outreach) and those that investigate the initial applications of such science for the ATM sector (application-oriented research).
- Strategic area of operatio**n 3 – Deliver industrial research and validation**. The second phase of the pipeline for innovation is IR, which includes applied research, pre-industrial development and validation projects. It aims to progressively deliver SESAR Solutions (i.e. specific operational or technical improvements) that are systematically validated to support a smooth transition to deployment. This phase also includes the fast-track innovation and uptake, as established in subparagraph 2.2.1.2.
- Strategic area of operation **4** – **Facilitate an accelerated market uptake of SESAR Solutions**. The third phase of the pipeline for innovation deals with DSDs, which are designed as and instrument to accelerate market uptake for a critical mass of early movers. They are managed in synergy between CINEA and the JU and an integral part of the SESAR 3 Programme as defined in subparagraph 2.2.3.2., 'SESAR 3 JU's contribution to Digital Sky Demonstrators', above. This area of operation also includes the activities related to the close coordination with EASA in order to enable timely development by EASA of regulatory measures that fall under Regulation (EU) 2018/1139 and the relevant implementing rules. Finaly this area also coveres all supporting activities of the JU to the related standardisation activities, in close cooperation with standardisation bodies and EASA, as well as with the entity established to coordinate the tasks of the SESAR deployment phase in line with Commission Implementing Regulation (EU) No 409/2013.
- Strategic area of operation **5 – Deliver SESAR outreach (Cooperation, synergies and cross-cutting themes and activities)**. The SESAR 3 JU ensures global outreach relating to the ATM Master Plan and the ongoing and planned SESAR activities, in full coordination with the its members and stakeholders.

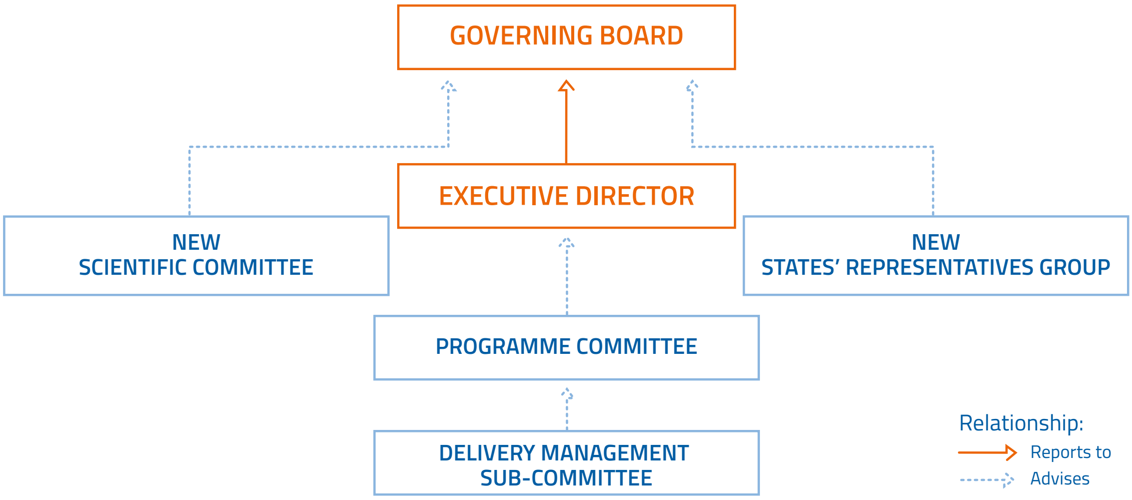
The SESAR 3 JU ensures it operates fully in accordance with its obligations, while also striving continually to improve its financial, administrative and corporate management, as these elements of the SESAR 3 JU's operations remain an integral part of the delivery of its mission and values.

[24] COM(2020) 579, Amended proposal for a regulation of the European Parliament and of the Council on the implementation of the single European sky (recast).

3. SESAR 3 JU GOVERNANCE

With reference to the basic act of the SESAR 3 JU, the governance is depicted in the following figure:

FIGURE 10: **SESAR 3 JU GOVERNANCE**



3.1. SESAR 3 Joint Undertaking governing bodies

3.1.1. Governing Board

The Governing Board is the main governance body of the SESAR 3 JU. It is responsible for the strategic orientation and the operations of the Joint Undertaking and supervises the implementation of its activities.

Its composition, functioning and tasks are defined in Articles 15-17 and 149-151 of the SESAR 3 JU's basic act.

The composition of the SESAR 3 JU Governing Board is defined in Article 149 of the basic act. The members other than the EU (referred to in point b of that Article) include the founding members and any associated members that may be selected in accordance with the provisions of Article 7 of the basic act.

3.1.2. Executive Director

Appointed by the Governing Board, the SESAR 3 JU's Executive Director is the chief executive responsible for the day-to-day management of the Joint Undertaking in accordance with the decisions of the Governing Board.

His or her tasks are defined in Articles 19 and 152 of the basic act.

3.1.2.1. SESAR 3 JU Programme Committee

In a consultative role, the Programme Committee supports the Executive Director in the execution of his/her responsibilities, in particular by:

- monitoring both operational and financial progress, as well as issues and risks, at programme level;
- identifying the impact and proposing means of mitigation for risks and issues whether programmatic, resource related, technical or operational, at programme level;

- providing strategic guidance and making recommendations with regard to the management of the programme to secure progressive delivery through releases and ensure alignment with the European ATM Master Plan;
- establishing and pre-assessing the proposal from the SESAR 3 JU Members for the annual additional activities plan before submission thereof to the Governing Board; and monitoring its implementation after approval by the Governing Board;
- providing resource commitment and strategic programme advice in relation to operational, financial and contractual analysis for monitoring, investigation and possible changes to projects;
- making recommendations and/or suggestions focusing at the following tasks:
  - perform strategic planning and monitoring of the ATM modernisation efforts in Europe (ATM Master Plan),
  - implement the research and development aspects of the European ATM Master Plan (deliver SESAR solutions).
  - Facilitating an accelerated market uptake of SESAR Solutions (demonstrators with early movers, coordination with EASA to help evolve regulatory measures, support standardisation activities)

The SESAR 3 JU Executive Director will take into account the Programme Committee's recommendations and will report to the Governing Board on its work in addition to key activities and achievements reported in the SESAR 3 JU Annual Activity Report.

In undertaking its role, the Programme Committee will be supported by a sub-committee responsible for the programme "delivery management" and is directly involved in the delivery of projects and contributions.

3.1.3. Advisory bodies

3.1.3.1. Scientific Committee

The Scientific Committee, the scientific advisory body of the SESAR 3 JU, supports the Governing Board in ensuring the scientific excellence of the Digital European Sky Programme.

Its role is defined in Articles 21 and 154 of the basic act and, in accordance with Article 154(1) it shall be referred to as the Scientific Committee.

3.1.3.2. States' Representatives Group

The States' Representatives Group supports the SESAR 3 JU's Governing Board in monitoring the programme progress of the Joint Undertaking; in updating strategic orientation in line with the Horizon Europe strategic planning and with other EU and Member States funding instruments; and in maintaining links to Horizon Europe and other EU, national and, where relevant, regional initiatives, including cohesion policy funds in line with smart specialisation strategies.

The representatives of the Member States will also present a coordinated position, taking into consideration the views expressed in the Single Sky Committee.

Its role is defined in Articles 20 and 153 of the SBA.

4. FINANCIAL RESOURCES AND PLANNED EXPENDITURE

4.1. Overall investment needs to achieve the targeted impact for the SESAR 3 JU

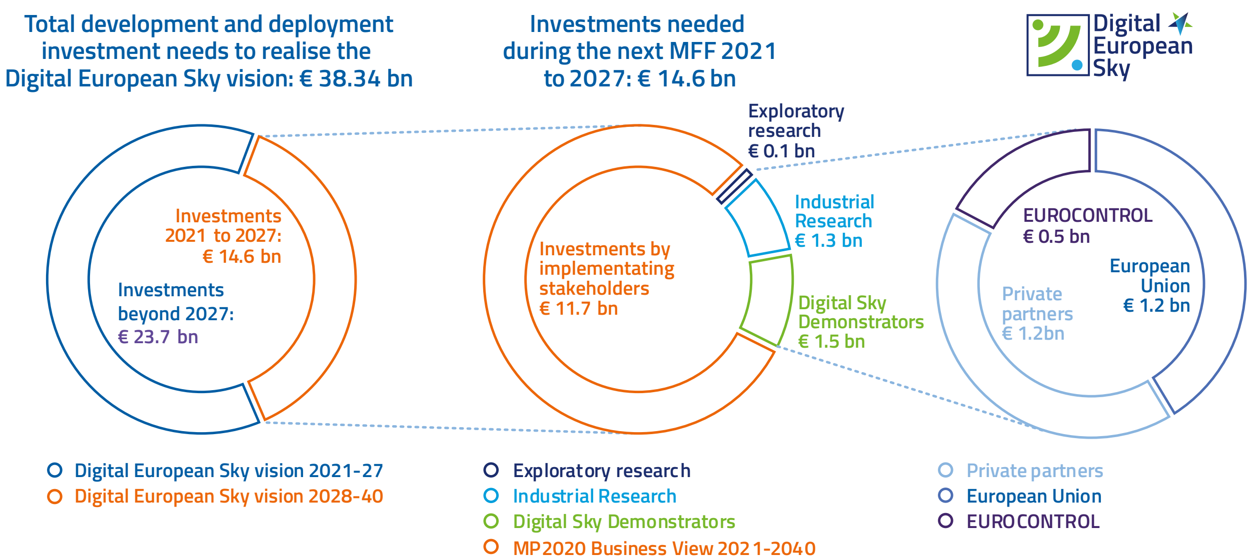
The vision, objective and expected impact of the SRIA can be achieved only by coordination with all stakeholders that develop, supply, operate, use and regulate ATM services and infrastructure supporting aviation in Europe, covering all TRLs.

In the SRIA, it is estimated that it will take a total investment of EUR 38.3 billion to complete the deployment of the Digital European Sky between 2021 and 2040, EUR 14.6 billion of which will need to be spent during the multiannual financial framework running from 2021 to 2027 (MFF for 2021–2027). Of these investments needed during the MFF, EUR 2.9 billion are needed to execute the R & I activities defined in this SRIA, broken down as illustrated in Figure 11 (read from right to left).

Approximately half of this investment in R & I should ideally be dedicated to accelerating the deployment of SESAR 2020 solutions (EUR 1.5 billion), mainly through the Digital European Sky demonstrator network. EUR 1.4 billion should be allocated to R & I on further solutions (Exploratory Research and Industrial Research) needed for phase D of the European ATM Master Plan. Of the EUR 2.9 billion needed to support the implementation of the SRIA, EUR 0.5 billion will come from Eurocontrol, while the remainder is foreseen to be evenly split between EUR 1.2 billion from the EU and EUR 1.2 billion from private partners, thus establishing an appropriate risk-sharing partnership.

The EU contribution to R & I activities (Exploratory Research and Industrial Research, funded under the Horizon Europe programme) is planned to be adequately calibrated at EUR 0.6 billion to cover the needs expressed in the SRIA for these types of activities.

FIGURE 11: **BREAKDOWN OF OVERALL INVESTMENT NEEDS TO ACHIEVE THE OBJECTIVES SET IN THE EUROPEAN ATM MASTER PLAN AND THE SRIA**



However, for the future partnership to also meet its objective in relation to facilitating an accelerated market uptake of SESAR solutions, the JU will require significantly more contributions from other sources of EU funding (CEF), which will be used to realise this specific objective (via separate delegation agreements) to match the ambition defined in the SRIA.

Indeed, a strengthened JU that will stretch all the way to facilitating the deployment processes with demonstration activities and ensuring the delivery of technical solutions able to advance smoothly through standardisation and certification processes should be able not only to advance technology readiness but also to stimulate digital aviation infrastructure investments in Member States throughout the duration of the 2021–2027 MFF.

4.2. Financial resources (revenues)

4.2.1. European Union financial contribution

The EU financial contribution from the Horizon Europe programme to the SESAR 3 JU, including European Free Trade Association appropriations, to cover administrative costs and operational costs will be up to EUR 600 million, including up to EUR 30 million for administrative costs. This amount is split between:

- Exporatory Research (ER): EUR 100 million;
- Industrial Research (IR): EUR 500 million.

Each of these envelopes (Exploratory Research, EUR 100 million; Industrial Research, EUR 500 million) will include up to 5 % for the running costs of the SESAR 3 JU. The overall EU contribution to the running costs of the SESAR 3 JU could amount to EUR 30 million.

In addition, the EU dedicates financial contributions coming from the CEF fund to the Digital European Sky programme. These amounts will be managed by CINEA and include financial resources for technical assistance by the SESAR 3 JU.

Participation in indirect actions funded by the SESAR 3 JU under Horizon Europe should comply with the rules set out in the Horizon Europe regulation. A single funding rate per type of action applies for all activities that it funds. The maximum rate per type of action is to be fixed in the Annual Work Programmes ([25]).

4.2.2. Contributions from Members other than the European Union

The EU financial contribution under the Horizon Europe programme is mirrored, for Industrial Research, by a contribution of EUR 500 million from the private Members and a contribution of EUR 500 million from Eurocontrol. These two contributions include EUR 25 million (5 %) each to cover the running costs of the SESAR 3 JU.

The contributions of Eurocontrol and of the private Members consist of:

- in-kind contributions to operational activities;
- in-kind contributions to additional activities, approved by the Governing Board;
- financial contributions, intended to cover the running costs of the SESAR 3 JU.

The in-kind contribution of Eurocontrol and of the private Members will take the form of a participation to Horizon Europe projects or other activities. Their eligible direct costs will be co-financed by the EU. The remaining part of eligible (direct) costs supported by the Members other than the EU will be their in-kind contribution to operational activities (IKOP), while their indirect costs above the flat rate will be part of their in-kind contributions to additional activities (IKAA). In order to reduce the gap between Members

[25] Article 34, Regulation (EU) No 2021/695 of the European Parliament and of the Council of 28 April 2021 establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, and repealing Regulations (EU) No 1290/2013 and (EU) No 1291/2013.

with a low level of indirect costs and Members with a higher level of indirect costs (which would change the co-financing rate against the total project cost), the Members will be invited to commit to the Governing Board a predefined level of contribution, including in-kind contributions to operational activities and all possible kinds of in-kind contributions to additional activities.

4.2.3. Revenues for the SESAR 3 JU running costs

The above will result in the running costs of the SESAR 3 JU being financed until 31 December 2031, with contributions from:

- the EU, of up to EUR 30 million;
- Eurocontrol, of up to EUR 25 million;
- the private members, of up to EUR 25 million.

This represents a total amount of EUR 80 million, to which are added 'technical assistance fees' from the Commission in relation to the Digital Sky Demonstrator activities (up to EUR 1.75 million for a first tranche of two calls for proposals).

The SESAR 3 JU will make its best efforts to use the remaining SESAR 2020 financial contributions still due by the Members other than the EU for as long as possible, with the intention that the first instalment of the financial contribution to the SESAR 3 JU would not be called for before 2023 or even 2024, depending on the actual cash flow needs of the JU. Financial contribution to SESAR 2020 was a seven-year commitment, as the commitment to SESAR 3 JU will be, for all Members. It should be avoided, in particular in the crisis context, that Members participating in both programmes have to pay two contributions at the same time.

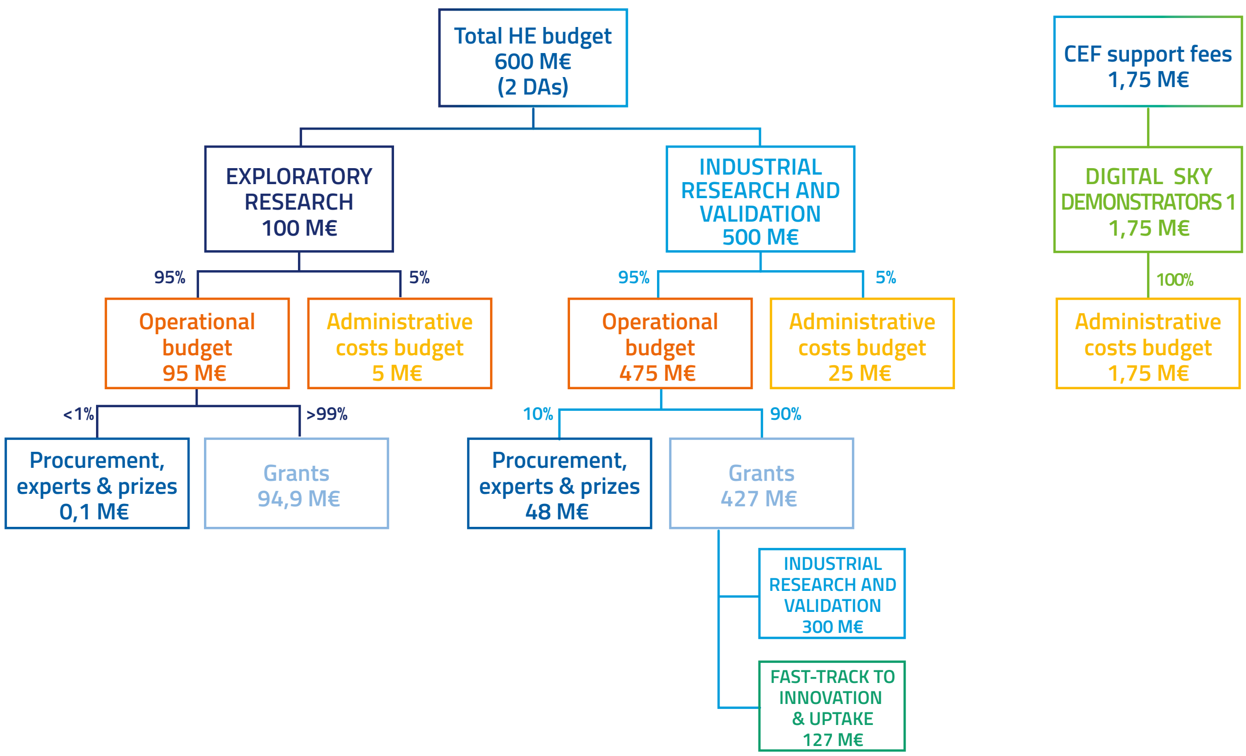
4.3. Expenditure (European Union)

The EU financial contribution covers expenditure, broken down as laid out in Figure 12.

The planned amount per call is provided in paragraph 2.2.3.3. 'Budget allocation (EU contribution) to calls for proposals' above. Moreover, of the EUR 475 million of operational appropriations for Industrial Research, an amount corresponding to about 10 % could be reserved for actions through procurements (support and advisory services) and prizes.

Further information on the planned expenditure breakdown appears in annex F. 'Multiannual budget (operational expenditure)', below.

FIGURE 12: **SESAR 3 JU BUDGET ALLOCATION (EU PART) PER PHASE OF THE INNOVATION PIPELINE**



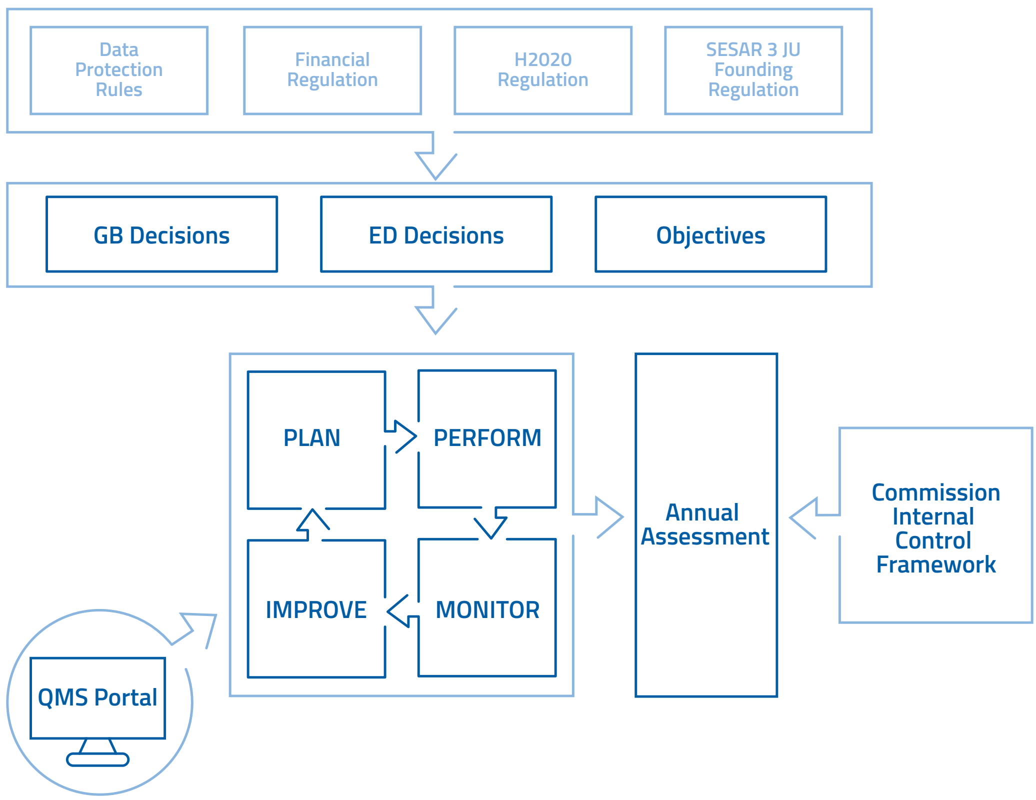
5. ORGANISATIONAL MANAGEMENT AND INTERNAL CONTROL SYSTEMS

5.1. Strategy for organisational management and internal control systems

The SESAR 3 JU implements the Commission's internal control framework (ICF) through its Quality Management System (QMS) ([26]), accessible via a portal on the SESAR 3 JU's information technology (IT) system. The QMS is implemented to help the SESAR 3 JU in achieving its objectives and optimising its value to stakeholders. The SESAR 3 JU's Quality Manual describes the approach, which is represented in Figure 13.

The achievement of SESAR 3 JU objectives (including the performance of the QMS) is assessed annually for its suitability and effectiveness and reported through an implementation of metrics to be presented in the

FIGURE 13: **THE SESAR 3 JU IMPLEMENTATION OF THE INTERNAL CONTROL FRAMEWORK**



26 The quality management approach at the SESAR JU has been defined and adopted through SJU/ED/395.

consolidated annual activity report. The QMS allows for the management of these metrics.

5.1.1. The quality management system of the SESAR 3 Joint Undertaking

The SESAR 3 JU quality manual includes a defined strategy to deploy a quality management system (QMS) and applies continual improvement through a 'plan–do–check–act or improve' (PDCA) cycle. This continual improvement cycle applies to all the processes used at the SESAR 3 JU to comply with its obligations and to deliver its expected results. It also involves the tools related to these processes, and the people who use these tools and processes. The SESAR 3 JU application of the PDCA cycle is summarised below.

Plan

The Multiannual Work Programme (MAWP) is the primary planning tool for the SESAR 3 JU, updated and complemented each year through the Annual Work Programme (AWP), and by lower-level objectives set by the Executive Director with the Corporate Management Team.

Do

The SESAR 3 JU meets its objectives through the execution of its processes and the adequacy of these processes for meeting the objectives. Ensuring the stability of the processes and their alignment with the strategic goals and objectives is key to the SESAR 3 JU's performance and to ensuring that stakeholder requirements can be met, which will, in turn, help build stakeholder confidence.

Roles and responsibilities with regard to process management are established. Process definitions, together with a comprehensive process map, are published through the QMS Portal. By monitoring the adherence to these processes, the QMS helps the SESAR 3 JU achieve these results.

Check or monitor

Several structures have been put in place, in the SESAR 3 JU's constituent act or other regulations, or by decision of the Executive Director (ED decisions), to monitor the SESAR 3 JU's activities. The structures benefit from the inputs of the QMS regarding the adherence of the SESAR 3 JU to its processes, and the adequacy of such processes. These structures include the following:

- the Governing Board,
- the Executive Director, including his/her role as Responsible Authorising Officer,
- the Corporate Management Team,
- the Quality and Information and Communications Technology (ICT) Committee (QICT Committee),
- the Internal Audit Capability (IAC),
- project audits,
- the periodic reporting, including the annual reporting through the Consolidated Annual Activity Report.

The SESAR 3 JU's activities are monitored against a set of objectives, which are introduced in chapter 5.2. 'Monitoring the activities of the SESAR 3 JU', below.

Act (Improve)

As a result of monitoring activities, the SESAR 3 JU routinely initiates change and improvement initiatives.

5.1.2. Annual assessment

The SESAR 3 JU will carry out annual reviews to assess and monitor the performance of the SESAR 3 JU, using the inputs from the QMS according to the Internal Control Framework introduced by the European Commission in 2017 ([27]), by assessing each of the 50 characteristics of the 17 principles across the five components of the Internal Control Framework.

The CAAR will report on the consolidated ratings for the 17 principles.

5.2. Monitoring the activities of the SESAR 3 Joint Undertaking

Several structures are in place to monitor the SESAR 3 JU's activities. These structures benefit from the inputs of the QMS regarding the adherence of the SESAR 3 JU to its processes, and the adequacy of such processes.

Monitoring mechanisms include the objectives set, along with the definition and maintenance of indicators; the risk management activities; and the IAC.

[27] Communication to the Commission from Commissioner Oettinger C(2017) 2373 on the 'Revision of the Internal Control Framework'.

5.2.1. Setting objectives

To monitor its activities, the SESAR 3 JU will apply a procedure that starts with setting objectives, which is twofold: general and strategic objectives applicable throughout the programme, and operational objectives. Through the link between operational objectives and general objectives, the SESAR 3 JU ensures consistency in its operations throughout the years.

General and strategic objectives and overall principles are set in this Multiannual Work Programme. These are as follows:

- the general objectives stemming from the Horizon Europe regulation,
- the general objectives common to all joint undertakings, as set in the SESAR 3 JU's constituent act, Part I 'Common provisions',
- the objectives and tasks specifically defined for the SESAR 3 JU in title VIII 'Single European Sky ATM Research 3 Joint Undertaking' of Part II of its constituent act, as identified in chapter 1.3. 'Specific objectives of the SESAR 3 JU', above. These are the strategic objectives;

To implement these general objectives and principles, **operational objectives** are set as part of the annual programming process:

- other objectives and principles defined in the present document and in subsequent annual work programmes,
- objectives and obligations stemming from other applicable regulations, such as from the Financial Regulation[28] or the Internal Control Framework;
- objectives or principles defined to mitigate major corporate risks or to leverage opportunities affecting the SESAR programme, as per the risk management approach presented in paragraph 5.2.2. 'Risk management', below.

These operational objectives drive the SESAR 3 JU's day-to-day activities and are linked with indicators (i.e. method or means through which the achievement of the operational objective is measured) and targets (expected quantitative or qualitative value of the indicator) to be achieved within the year.

[28] Regulation (EU, Euratom) 2018/1046 of the European Parliament and of the Council of 18 July 2018 on the financial rules applicable to the general budget of the Union (EU financial regulation) (OJ L 193, 30.7.2018, p. 1).

5.2.2. Risk management

Risk management aims to fulfil the SESAR 3 JU's mission, strategic and operational objectives by anticipating, proactively identifying, analysing, treating, monitoring and controlling risks. The objectives are to:

- enable informed decision-making at any level of the SESAR 3 JU activities, including information on risks and opportunities and how to best manage them;
- mitigate the impact of risks, defining and ensuring the implementation of appropriate action plans;
- seize opportunities and enhance their benefits;
- meet legal and regulatory requirements;
- establish and implement internal control.

This activity is connected to the multiannual and annual programming cycle for which it provides up-to-date information on critical risks affecting the strategic objectives of the SESAR 3 JU (as documented in the Multiannual Work Programme and subsequent Annual Work Programmes). Moreover, it feeds into a corporate reporting process for which it provides up-to-date information on the response to critical risks and the completion of action plans (as documented in the consolidated annual activity report).

To that aim, the process combines a continuous approach (risks and opportunities are identified and managed continuously) and a periodic biannual management review cycle.

The key principles of risk management focus on critical risks in order to maximise effectiveness and efficiency. A risk should be considered as critical if it can:

- endanger the realisation of objectives outlined in the European ATM Master Plan;
- cause serious damage to the SESAR partners (SESAR 3 JU members, the broader stakeholder community involved in the execution of the European ATM Master Plan, as mentioned in paragraph 2.3.2 'Stakeholders engagement', above);
- result in critical intervention at political level (Commission/Council/Parliament) regarding SESAR 3 JU's performance;
- result in infringement of laws and regulations;
- result in misuse of public money;
- put the safety levels of aviation at stake;
- or in any way seriously impact the SESAR 3 JU's image and reputation.

The scope of risk management encompasses all risks linked to the SESAR 3 JU activities, organised in threads.

The first thread concerns the corporate risks, which are as follows:

- risks impacting the strategic objectives of the organisation or the safeguarding of its assets and staff integrity,
- major top risks from the other three threads,
- risks escalated from the other three threads.

The second thread is associated with the Master Plan risks, which are linked to the execution of the entire Master Plan, including the three levels (level 1, the executive view; level 2, the planning and architecture view; and level 3, the implementation view). This thread comprises risks shared with other organisations involved in the execution of the Master Plan, such as deployment of SESAR.

The third thread encompasses all SESAR 3 JU internal risks whether they are in the domains of finance and budget, human resources, legal and procurement, ICT etc.; it concerns the whole SESAR 3 JU organisation.

The fourth thread includes risks linked to the entire Digital European Sky Programme and focuses on risks impacting the execution of the programme. Some of these risks are escalated from the projects, others are identified at Programme level.

Risks are identified and recorded in a risk-register system, along with associated information including the cause, origin, opportunities and/or mitigation options, uncertainties and risk impact. Major risks and the follow-up mitigation actions and planning are escalated and reported, including up to the Governing Board.

5.2.3. SESAR 3 Joint Undertaking indicators

Indicators and their related targets are used to track the achievement of the objectives. There are three categories of indicators: **cross-cutting indicators**, linked with the general objectives set for all Joint Undertakings under the Horizon Europe programme; **key performance indicators**, linked with the strategic objectives, used consistently throughout the life of the Digital European Sky programme and with a target to be achieved by the end of the programme; and **operational indicators** related to operational objectives set in the annual work programmes.

Reporting on the indicators and the achievement of the objectives will be done in the context of the consolidated annual activity report submitted by the

Executive Director and assessed by the SESAR 3 JU Governing Board, in accordance with Articles 16 (n) and 18-4.(e) of the SESAR 3 JU's basic act.

5.2.3.1. Cross-cutting indicators

Cross-cutting indicators are meant to help the SESAR 3 JU monitor the implementation of the general objectives of the Horizon Europe regulation, and of the general objectives common to all joint undertakings, as set in the SESAR 3 JU's constituent act Part I 'Common provisions'.

These indicators are being developed by the European Commission in collaboration with partners on the basis of the Horizon Europe guidance. The table below provides an indicative list of such indicators, available at the time of drafting. It will be updated based on the final outcome of the preparatory works.

5.2.3.2. Key performance indicators

Key performance indicators of the Digital European Sky programme / SESAR 3 JU are defined in relation to its strategic objectives (see chapter 1.3 'Objectives of the SESAR 3 JU', above). Some of these indicators represent a higher-level view on operational indicators that are defined on a rolling basis in the Bi-Annual Work Programmes for reporting purposes.

TABLE 5: **CROSS-CUTTING INDICATORS**

Regulatory basis	Cross-cutting indicators
SBA Art. 4 **SBA Art. 5**	Financial (€) and in-kind contributions, committed and actual [direct leverage]
	Additional investments triggered by the EU contribution, notably for exploiting or scaling up results (linked to but outside the partnerships, including qualitative impacts and success stories) [indirect leverage]
	Overall (public and private, in-kind and cash) /Additional investments mobilised towards EU priorities
	International actors involved
	Share & type of stakeholders and countries invited/engaged
	No and types of newcomer partners in partnerships and countries of origin (geographical coverage)
	vNo and types of newcomer organisations in supported projects (in terms of types and countries of origin)
	Number and type of coordinated and joint activities with other European Partnerships
	Number and type of coordinated and joint activities with other R&I Initiatives at EU /national/ regional/sectorial level
	Complementary and cumulative funding from other Union funds (Horizon Europe, National funding, ERDF, RRF, Other cohesion policy funds, CEF, DEP)
	Visibility of the partnership in national, European, international policy/industry cycles

TABLE 6: **KEY PERFORMANCE INDICATORS OF THE SESAR 3 JU**

Regulatory basis	Key performance indicators
SBA Art. 142 **SBA Art. 143**	Share of total budget committed
	Number of grants signed per R&I pillar
	Number of SESAR Solutions delivered at TRL6
	Share of SESAR Solutions available for deployment (TRL6) against the ambition set-out in the European ATM Master Plan
	Number of SESAR Solutions which have supporting standards and regulations in place to facilitate market uptake beyond TRL6 (in coordination with EASA and standardisation bodies)
	Share of SESAR Solutions that are in deployment in at least 20% of EU Member States (on a voluntary or regulated/mandated basis)

5.2.3.3. Operational indicators

Operational indicators are related to operational objectives of the SESAR 3 JU and will be defined in the context of the work programmes. Some of these indicators follow a consistent scheme across the work programmes and/or may be recurrent over years.

5.2.4. Internal Audit Capability

Whereas internal control is carried out by management and staff, the independent assessment of internal control is ensured by the setting up of an IAC, as per article 30 of the draft Council regulation establishing the Joint Undertakings under Horizon Europe.

The IAC provides the Executive Director with assurance as to the effectiveness and efficiency of the governance, risk management and control processes in the SESAR 3 JU, taking into account the specific nature and contributions of its private partners and of a pan-European organisation (Eurocontrol). In this way, it promotes a culture of ethics and efficient and effective management within the SESAR 3 JU.

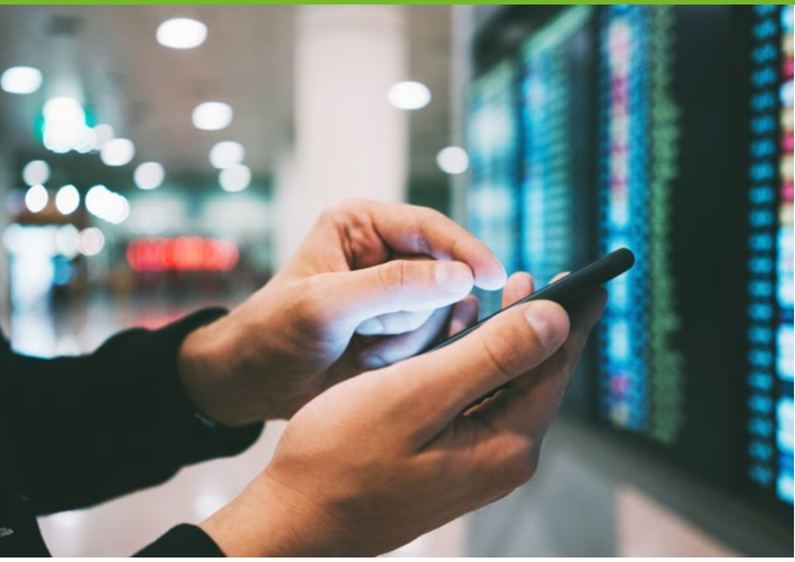
This is done with special reference to the following aspects:

- risks are appropriately and continuously identified and managed;
- significant financial, managerial and operating information is accurate, reliable and timely;
- the SESAR 3 JU's policies, procedures and applicable laws and regulations are complied with;
- the objectives of the SESAR 3 JU are achieved effectively and efficiently;
- the development and maintenance of high-quality control processes are promoted throughout the SESAR 3 JU.

To this end, the IAC can perform both assurance and consulting engagements.

With this, the IAC will assist the Executive Director to implement his/her tasks as described in Articles 19 and 152 of the Council Regulation establishing the joint undertakings under Horizon Europe, notably to:

- ensure sustainable and efficient management of the joint undertaking;
- establish and ensure the functioning of an effective and efficient internal control system;
- protect the financial interests of the EU by applying preventive measures against fraud, corruption and any other illegal activities by means of effective checks.



5.3. Efficiency gains

The SESAR 3 JU develops a strategy to secure efficiency gains. It will benefit from efficiency measures and synergies already implemented in the context of the SESAR JU from 2008 to 2021, which will be continued. These are as follows.

- **Collaboration with Eurocontrol.** Considering that Eurocontrol possesses an appropriate infrastructure and the necessary administrative, IT, communications and logistics support services, the SESAR 3 JU should benefit from such infrastructure and services. In this context, there are few potential synergies that could be gained from pooling administrative resources with other Joint Undertakings through a common back office. For this reason, the SESAR 3 JU has opted out of the common back office functions established by the single basic act.
- **Collaboration with the European Commission.** The SESAR 3 JU will leverage synergies from the use of the European Commission's ICT systems and services (such as contracts with ICT service providers and suppliers). ICT systems supplied by the Commission are, in particular, related to:
  - financial management and accounting systems (accrual-based accounting);
  - human resources management (SysPer);
  - the management of Horizon Europe calls for proposals and grants;
  - procurement (e-procurement);
  - document management, namely the use of the Advanced Records System (ARES) (the European Commission's document management system);
- **Quality management.** The SESAR 3 JU undertakes regular process improvement initiatives in the context of the QMS, supervised by the QICT Committee, in order to monitor effectiveness and efficiency of business processes and IT tools, and focus on value-added activities.
- **Information and document management.** The QICT Committee also supervises the implementation and continuous improvement of the JU's Information and Document Management System (IDMS), which aims to simplify and streamline the management of information and documentation within the organisation. The IDMS is based on software implemented in 2017 and has been under constant improvement since then. The implementation of modules in ARES will also streamline communication with Commission services.
- **Electronic workflows.** The managed configuration of electronic systems supporting quality and information processes and key workflows that can be operated either locally or remotely makes teleworking measures possible with limited impact on the SESAR 3 JU's business continuity. This is thanks to the effectiveness of the JU's ICT system, which includes collaboration platforms and electronic workflows that, in combination with accrual-based accounting system workflows, support the most critical processes bound with strict deadlines.
- **Staff mission management.** Made possible through the increased use of video conferences, the number of missions has been reduced, especially for recurring monitoring activities such as project reviews. This represents a significant benefit in terms of environmental footprint, efficiency and work–life balance.

The SESAR 3 JU will develop close cooperation and ensure coordination with other European partnerships, when appropriate, through joint calls.

Furthermore, in accordance with the Financial Regulation, whenever there is a possibility for realising efficiency gains, the SESAR 3 JU and other EU institutions and bodies concerned may carry out the procedure and the management of the subsequent contract or framework contract on an inter-institutional basis under the lead of one of such contracting authorities.

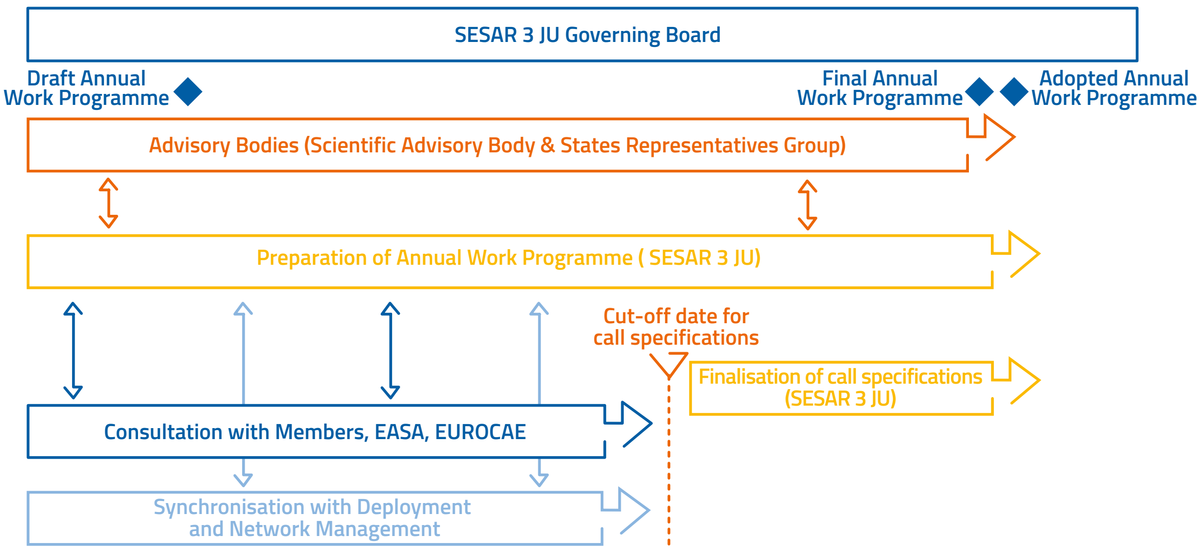
6. ANNUAL WORK PROGRAMMES DEVELOPMENT AND ADOPTION PROCESS

As stated in the introduction (section 1, 'Introduction', above), the present Multiannual Work Programme will be implemented through annual work programmes developed by the SESAR 3 JU and adopted by the Governing Board. Each annual work programme will detail the principles set out in the present Multiannual Work Programme and further define them into concrete activities and provisions, for example the call conditions of each call for proposals as per the framework set out in paragraph 2.2.3. 'Calls for proposals' above, for the full duration of the actions ([29]). Annual work programmes will also serve as financing decisions for these calls for proposals.

To ensure alignment with the overall objectives of the Digital European Sky programme, the SESAR 3 JU will, from 2023 onwards (i.e. starting from the development of the Bi-Annual Work Programme for 2024-2025), follow a clear and coordinated procedure in developing its annual work programmes, which includes consultation with the industry, the scientific community and the Member States. This procedure aims to support the SESAR 3 JU in developing the annual work programme development and to support the Governing Board in its adoption decision.

In the **preparation of annual work programme**, the SESAR 3 JU defines, for each year of the covered period (typically two years), the annual objectives

FIGURE 14: DEVELOPMENT AND ADOPTION OF ANNUAL WORK PROGRAMMES



29 To allow the SESAR 3 JU to fulfil its obligations set forth in Article 29(2) SBA, the Governing Board may adopt annual work programmes for the full period of implementation of the actions, i.e. for two years, in the form of bi-annual work programmes. These will be adopted every two years, with an amendment in the beginning of the second year to confirm the availability of EU budget approved at the time of adoption of the work programme.

and the related activities and resource plan including financial resources and budget for the given years). When relevant, this includes call conditions of the call(s) for proposals to be launched in the year, in which the Topics to be addressed are identified and described on the basis of the R & I needs defined in the nine SRIA flagships (see above in paragraph 2.2.2. 'R & I needs addressed in the SESAR 3 research and innovation programme', and in Appendix B 'SRIA flagships and their R & I needs'). This initial list and high-level description of Topics (at this stage, not at Solutions or projects level) is accompanied by other call conditions:

- reference to the basic act and the budgetary line,
- overall call budget (at this stage, indicative),
- type of action and related funding rate,
- high-level budget allocation per Work Area or Topic (indicative at this stage),
- application of the HE Work Programme and General Annexes,
- call timeline,
- eligibility, selection and award criteria (in relation to the type of action).

Consultations on that work programme take the form of an iterative process along two aspects:

- consultation with the advisory bodies in accordance with the SESAR 3 JU governance (see above in Section 3, 'SESAR 3 JU governance', above):
  - with the **Scientific Committee** to guarantee the scientific relevance of the Annual Work Programme, in particular the call Topics,
  - with the **States' Representatives Group** to guarantee its policy relevance and, as required, the adjustment to new or updated objectives;
- consultation with the SESAR 3 JU Members, the EASA and EUROCAE to secure the effective transition between the different (bi-)annual work programmes: for instance, this aims to secure effective integration within the SESAR innovation pipeline (between phases) and within a phase through the content, scope and expected outcomes of the calls for proposals.

The SESAR 3 JU also seeks synchronisation with deployment and network management to collect comments on the project plans and call Topics with the main objectives being to ensure consistency and synchronisation with the deployment needs in relation to Common Projects.

The preparation of the work programme results in a first intermediate milestone when a first draft version of the (bi-)annual work programme is submitted to the Governing Board for review.

Once this is done, the SESAR 3 JU proceeds with the development of the (bi-)annual work programme. At that stage, at the 'cut-off date for call specifications', consultations with the industry (members) and the deployment management and network management in relation to the call content are closed, and the '**finalisation of call specifications**' phase is carried out by the SESAR 3 JU in isolation. Other elements of the work programme, including the consolidation of members' proposals for additional activities, in line with articles 16 (l) and 147 of the basic act, are further developed with a continued consultation with the industry and the Advisory Bodies.

The final version of the (bi-)annual work programme is subject to a last formal consultation round with the two Advisory Bodies (Scientific Advisory Body and States' Representatives Group) who provide the Governing Board with their opinion, and is then submitted to the Governing Board in view of its adoption. This adoption is the financing decision authorising the launch of the calls and other actions of the (bi-)annual work programme, and the use of the related budget. This adoption is however subject to confirmation of the availability of EU budget for the action(s) and as per planned expenditure, in the beginning of the second year when a major amendment of the (bi-)annual work programme is required. The consultation of advisory bodies and of Members, EASA and EUROCAE will be required for this major amendment.

This procedure will be refined with clear milestones and dates in relation to each upcoming annual work programme, starting from 2023 for the development of the 2024-2025 Bi-Annual Work Programme - the 2022-2023 Bi-Annual Work Programme being directly derived from this Multi-Annual Work Programme document.

ANNEXES

A. European ATM Master Plan (2020 Edition)

The following sections are extracts of the key elements of the ATM Master Plan 2020 that can be found in the SESAR 3 JU website at https://www.sesarju.eu/masterplan2020.

A.1 The SESAR vision

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

The vision builds on the SESAR target concept and primarily on the notion of TBO, which enable airspace users to fly their preferred flight trajectories, delivering passengers and goods on time to their destinations as cost-efficiently as possible. This will be enabled by a new architecture referred to as the 'digital European sky', in which resources (on the ground and in the air) are connected and optimised across the network and irrespective of altitude (up to and including super-high-altitude operations), class of airspace or aircraft performance (manned or unmanned), leveraging modern technology through a data-rich and cybersecure connected digital ecosystem. In this environment, service providers will be able to collaborate and operate as if they were one organisation, with both airspace and service provision optimised according to traffic patterns. This architecture is also more compatible with the overall global vision for a more profound evolution of core ATM capabilities driven by new forms of traffic (drones and super-high-altitude operations)

A.1.1. Offering improvements across air traffic management

It is widely recognised that, to increase performance, ATM modernisation should look at the flight as a whole and not in segmented portions, and take account of parallel industrial evolutions. With this in mind, the SESAR vision embraces the entire ATM system, offering improvements at every stage of the flight.

A.1.1.1 Enabling a high level of network capacity and resilience

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

A.1.1.2 Improved flight trajectories, minimising the environmental footprint of aviation

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

Looking further into the future, innovative technologies and concepts, such as new aerial vehicles using hybrid propulsion and solar energy, will contribute to mitigating aviation's environmental footprint.

A.1.1.3 Improved airport performance and access

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

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

A.1.1.4 Enabling greater airborne automation

Advances in technologies, as well as capabilities inherent to new UAVs, will pave the way for higher levels of airborne automation. This will be facilitated by the development of an enabling framework for the integration and management of drones (through U-space) and larger RPAS alongside traditional manned aviation operations. At the same time, innovative traffic management solutions will be developed in order to enable greater levels of autonomy and connectivity in manned aviation. Airframes for commercial passenger transport will move from the current large aircraft with two crew members in the cockpit to a single crew member in the cockpit, that is SPO, paving the way for fully autonomous flights. Flights above FL660 (66 000 ft) will also be integrated, with entry and exit procedures through segregated or non-segregated airspace. These innovative airborne research concepts, when confirmed, will feed into and steer ATM research, first exploratory and then industrial. All these different environments will converge towards an integrated ATM in which manned and UAVs will operate in a seamless and safe environment using common infrastructure and services. All of this will enable the growth of the sector, particularly with regard to the use of large certified unmanned aircraft systems (UAS) for cargo and other civil operations, air taxis and smaller drones for a host of services (parcel delivery, medical emergencies, etc.).

A.1.1.5 Improved air navigation services productivity

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

A.1.1.6 Optimal use of air navigation service infrastructure and use of scarce resources

The move from physical assets to services, as well as standardisation between systems, will result in a rationalised aviation infrastructure. This is especially the case for CNS, which will rely on more integrated solutions, increased civil–military synergies and combined ground-based and satellite-based services. This rationalisation and integrated approach to CNS will result in a more efficient use and long-term availability of spectrum. Similarly, the virtualisation of ANS and the sharing of data services will enable the delivery of ATC services irrespective of the location of the infrastructure. Virtual control centres and use of remote towers will allow a more efficient and flexible use of resources, substantially improving the cost-efficiency of service provision.

As a result, ANSPs will have leaner, more modular and scalable systems that are easier to upgrade and more interoperable. Because of this, the system will become more resilient to unexpected traffic downturns or rapid returns to growth.

A.1.1.7 Increased global interoperability and enhanced collaboration

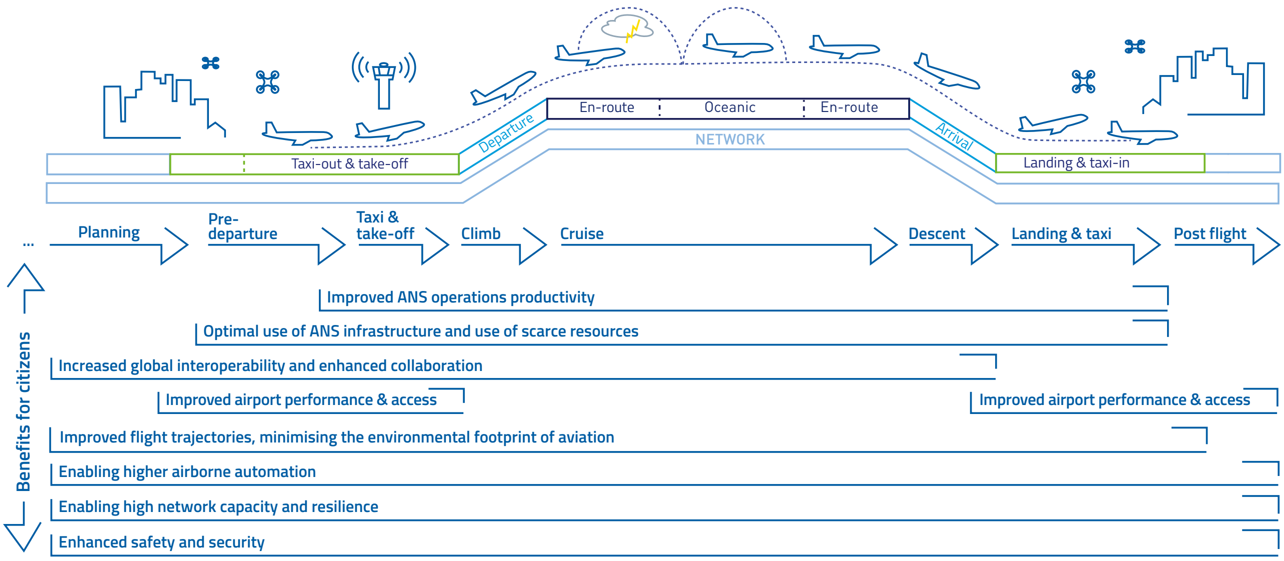
The exchange of trajectory, weather and aeronautical information made possible through information management, supported by SWIM, will enhance collaborative decision-making at network and global levels. Global interoperability will be improved through standardised interfaces for ATM information exchanges,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

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

A.1.1.8 Enhanced safety and security

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

FIGURE 15: **IMPROVEMENT AT EVERY STAGE OF THE FLIGHT**



A.1.2. Embracing the digital transformation of aviation

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

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

The strategy for digitalising European ATM responds to the need, expressed in the EU's aviation strategy, to digitalise Europe's aviation infrastructure and to respond to Europe's digital single market strategy[30]. The future European society and economy will build strongly on increased digitalisation. The ATM industry cannot fall behind and must consolidate its position at the forefront of innovation with a global perspective given the significant potential value for the European economy and citizens.

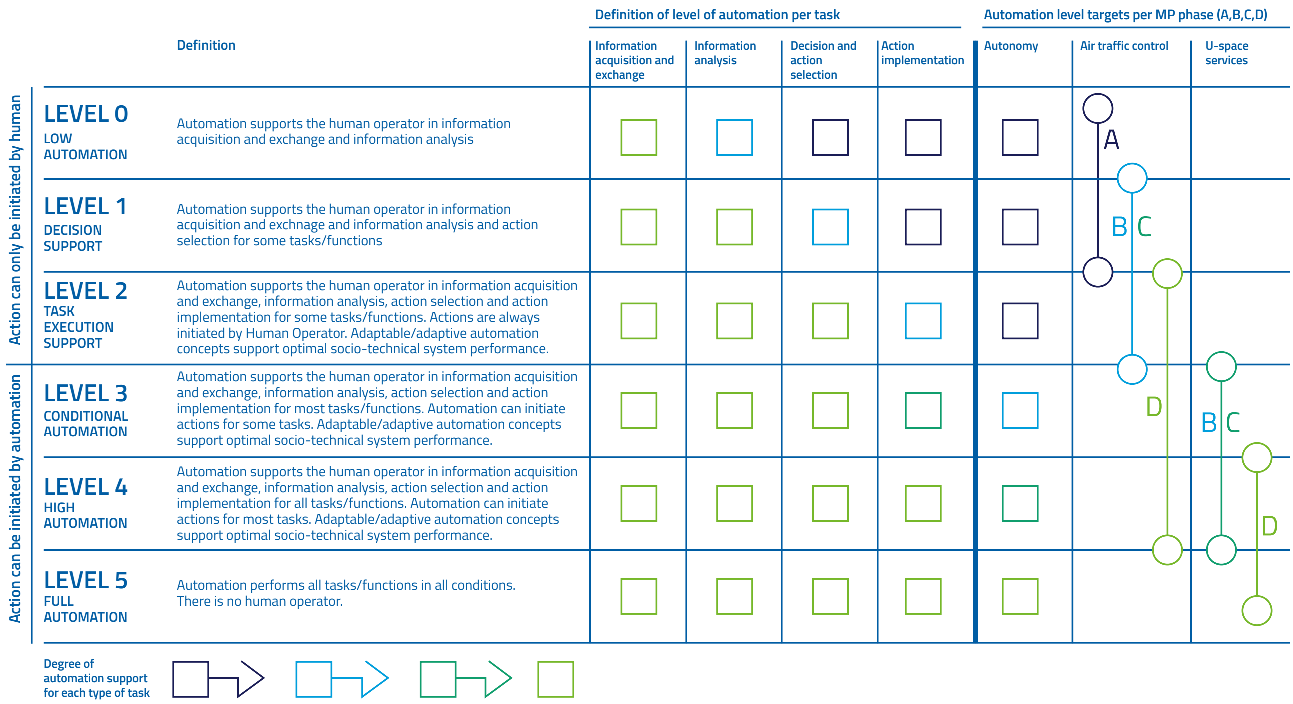
Digitalisation is a transversal topic affecting the full width of ATM, from concept of operations (CONOPS) to service provision, from safety-critical systems to passenger travel experience. Therefore, progress in this field must be visible.

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

30 COM(2015) 192 final

Figure 16 introduces an automation model for ATC based on the classic levels of automation taxonomy used by human performance and safety experts in the SESAR programme. It mirrors the five-level model from the SAE International (formerly known as the Society of Automotive Engineers) (ranging from level 0, 'low automation', to level 5, 'full automation'). It presents a simplified view of the overall level of automation in each of the ATM Master Plan phases (A–D) in two different areas: ATC and U-space services. It highlights the steps that it is envisaged will be taken towards the profound digital transformation outlined in the Master Plan.

FIGURE 16: LEVELS OF AUTOMATION



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

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

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

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

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

A.1.3. Delivering a Digital European Sky in four phases

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

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

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

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

A.1.3.1 Phase A: address known critical network performance deficiencies

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

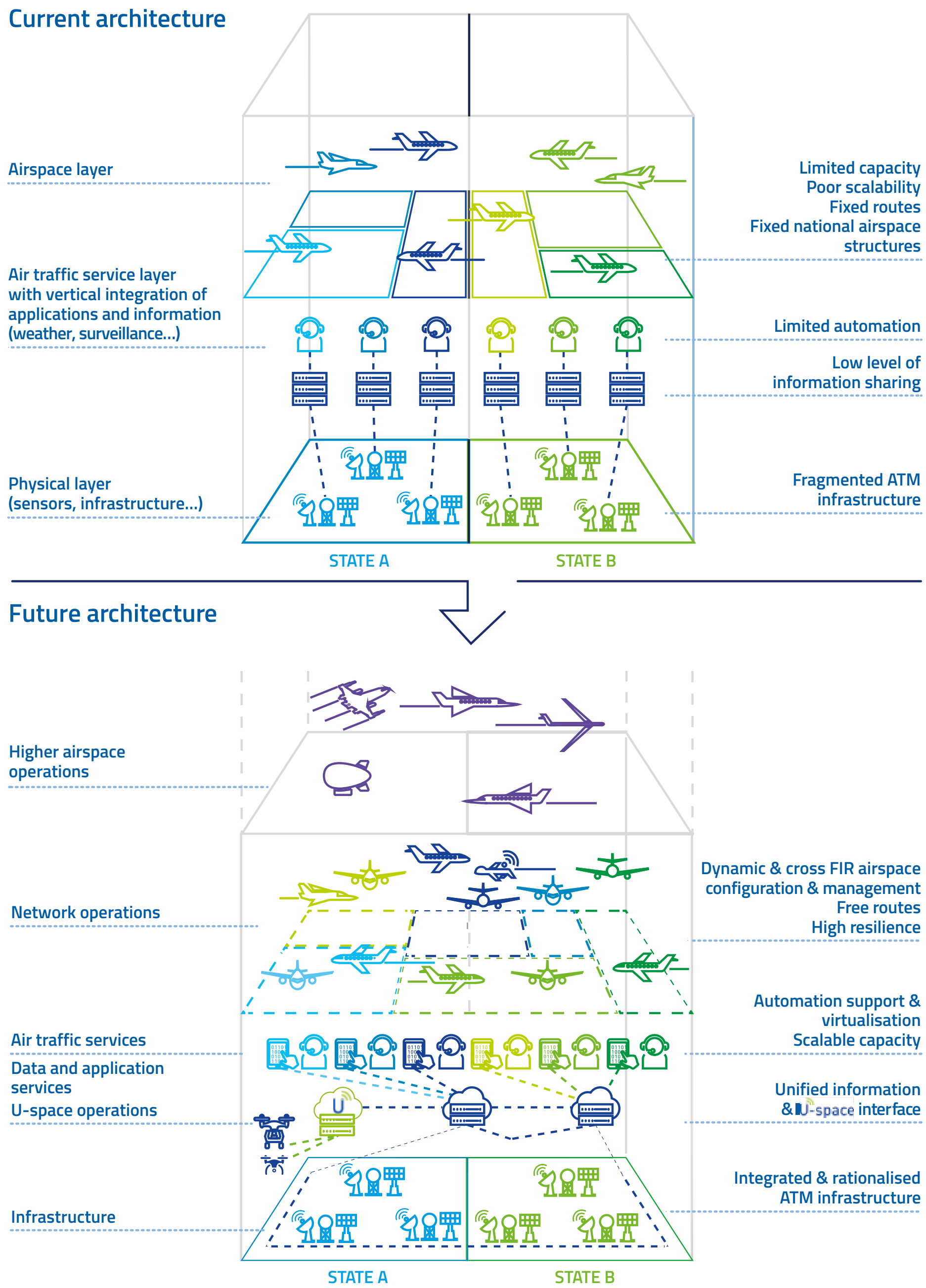
This approach allows increased information-sharing across national borders and exchange between ATM stakeholders, including the Network Manager, airlines, airports and the military. In this way, it targets both ground–ground and air–ground communications with the implementation of the SWIM blue profile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

This phase has already started, with the deployment of solutions delivered by SESAR and mainly, but not exclusively, through synchronised deployment[31].

A.1.3.2 Phase B: efficient services and infrastructure delivery

The development of open standards for ATM systems also means that stakeholders will find commonalities in terms of their operations and service needs, allowing for the development and introduction of a common service layer achievable through a set of ADSPs. This will make possible the optimisation and rationalisation of ATM support services, enabling a move from physical infrastructures to virtual infrastructures that are characterised by automation and increased sharing of data and information to enhance predictability and enable the remote provision of ATS.

FIGURE 17: **EVOLUTION OF THE EUROPEAN SKY**



31 Commission Implementing Regulation (EU) 2021/116 of 1 February 2021 on the establishment of the Common Project One supporting the implementation of the European Air Traffic Management Master Plan provided for in Regulation (EC) No 550/2004 of the European Parliament and of the Council, amending Commission Implementing Regulation (EU) No 409/2013 and repealing Commission Implementing Regulation (EU) No 716/2014 (Text with EEA relevance) C/2021/448

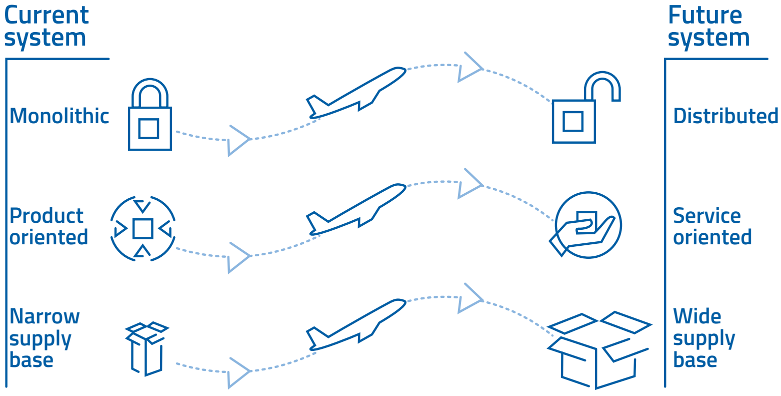
This phase is reliant on the delivery of a continuous flow of solutions from the SESAR 2020 R & D activities and demonstrable evidence of the related performance gains expected from Europe-wide and/or local deployment, where appropriate. In tandem with the more efficient organisation of infrastructure and services, this phase will see the business cycles of the traditional ATM stakeholders gradually start to shorten and move towards the accelerated cycles already seen with the integration of new entrants (e.g. drone operators, very high-altitude operators, mobility providers, U-space service providers (USSPs)) into the aviation environment.

A.1.3.3 Phase C: defragmentation of European skies through virtualisation

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

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

FIGURE 18: **TOWARDS A DIGITAL ECOSYSTEM**



A.1.3.4 Phase D: target vision: the Digital European sky

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

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

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

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

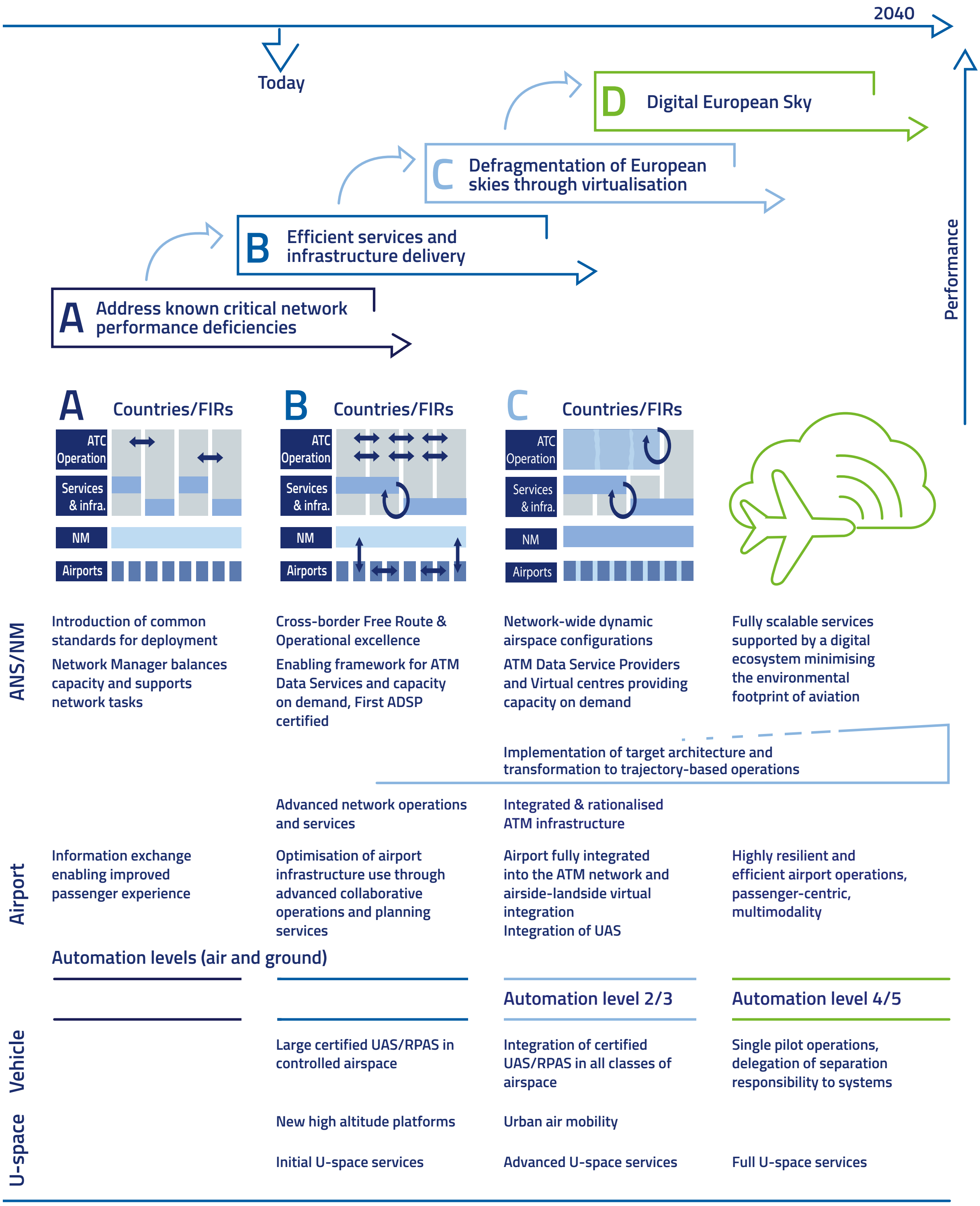
The full implementation of concepts such as infrastructure as a service, platform as a service and software as a service will enable the complete decoupling of service provision (infrastructure services, information services and all other ANS) from the physical location of the infrastructure. This will rely on hyperconnectivity between all stakeholders (ground–ground and air–ground) via high-bandwidth, low-latency fixed and mobile networks. Highly automated systems with numerous actors will interact with each other seamlessly, with fewer errors. Scaling of system performance will happen in quasi-real time, as and when required. In this context, multiple options can be envisaged for the reorganisation of services in relation to geography and flight execution (e.g. seamless collaboration between ANSPs across Europe and/or end-to-end ANS provision).

Many types of civil airspace users will be part of, or provide services to, providers of mobility as a service. This will offer customers a seamless and hassle-free travel experience combining different modes of transport for D2D journeys. Air taxis capable of autonomous vertical take-off and landing will provide new ways to connect airports with populated areas. For example, UAM will feature flying taxis operating at low and very low levels in urban and suburban areas, evolving from today's helicopters towards increasingly autonomous operations using alternative propulsion and new vehicle designs. UAM will be one of the most demanding use cases for U-space.

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

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

FIGURE 19: **FOUR-PHASE APPROACH FOR IMPROVEMENTS**



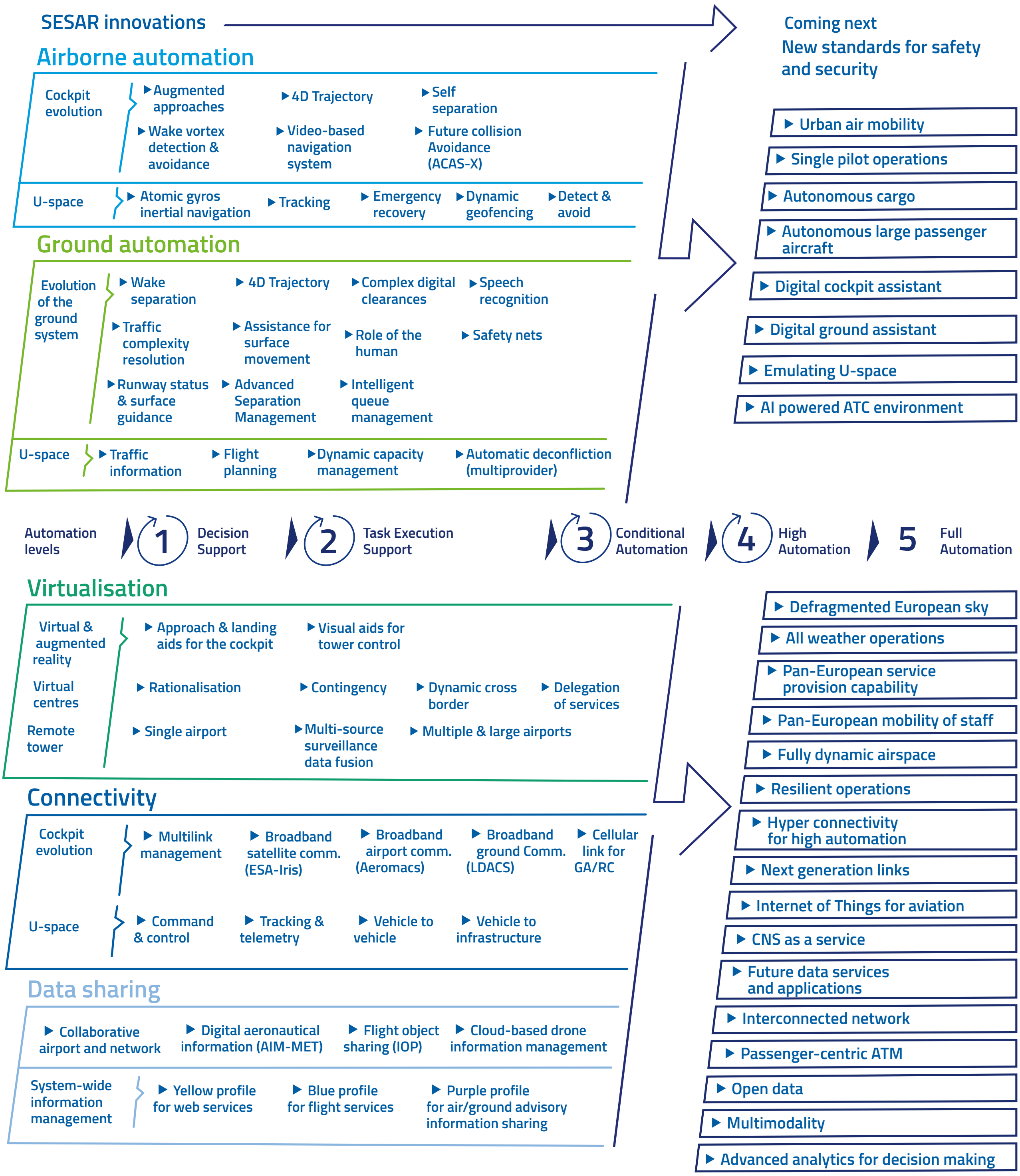
A.2 Delivering the Digital European Sky (phase D)

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

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

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

FIGURE 20: WHAT IS COMING NEXT



Future operations

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

In this context, research should deliver future operational solutions that will take advantage of modern techniques to address ATM performance.

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

Air/ground integration and autonomy

The progress made in the fields of machine learning and AI has opened the door to a myriad of applications in ATM. Many tasks in aviation that today can be performed only by humans can be automated in future, enabling an increase in the safety and scalability of the air traffic system.

AI-powered systems are expected to be integrated into the cockpit and into systems on the ground, which will open the door to air–ground machine-to-machine communication for trajectory management and much more. Aerial vehicles will evolve with the emergence of new trends, such as SPO, and new vehicles types, such as cargo and passenger drones. The electrification trend will continue to change aircraft characteristics and operations. U-space UTM is expected to use unprecedented levels of automation, which are likely to start making their way into traditional aviation. Research should explore if and in what ways automation can be used to deliver substantial and verifiable performance benefits while fully addressing safety concerns.

Themes: UAM, SPO, autonomous cargo, autonomous large passenger aircraft, automation level 3 and beyond for ground systems, U-space U3 and U4[32], RPAS in airspace classes A–G, ATM–U-space convergence.

Virtualisation serving scalability and resilience

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

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

Hyperconnectivity and machine-to-machine applications

The digital transformation of aviation will need to be backed up by an increase in connectivity capacity, speed and reliability. Different technologies and standards, such as 5G and satellite-based solutions will allow this to happen. The need to be always connected will become the new standard, both for safety-critical and non-safety-critical applications, including passenger experience. R & D is needed to develop a future concept for air–ground digital communications that will make it possible to overcome the current VHF limitations and enable growth. In addition, specific R & D may be undertaken to support the simultaneous use of multiple alternative means of data and

[32] U1 (foundation) services such as e-registration and e-identification; U2 (initial) services such as flight planning, tracking and collaboration with air traffic control; U3 (advanced) services such as conflict detection and avoidance and a more dynamic interface with ATC; and U4 (full) services which envisage full integration of U-space operations with manned aviation and air traffic control

voice communication between the flight deck and ATC, including using open links such as 5G secure connectivity.

The internet of things for aviation could be implemented. Machine-to-machine communication will open up possibilities for real-time and automatic decision-making to improve efficiency in various sectors of aviation.

Themes: next-generation links, networks and applications.

Data-sharing and data services

In the future, data-sharing through interoperable platforms and open data policies will allow collaboration between various actors and the optimisation of services and process. The sharing of data will allow the improvement and creation of data-based services such as big data analytics. Aviation is already a sector that generates a huge number of data. However, with the emergence of open data trends, the full potential of big data analytics in aviation can be explored. Data from various sources such as flights, air traffic or airports aligned with powerful analytics will allow for improvements and efficiency gains in many operations, such as predictive maintenance, route optimisation and personalisation of customer offers.

Ultimately, data services and information-sharing will allow better-targeted decision-making by all stakeholders. New data-sharing standards and systems will allow new 'as a service' businesses to emerge, allowing the creation of more value for aviation.

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

New standards for safety and security

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

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

A.3 The role of the human

A.3.1. An integrated view of the air traffic management system

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

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

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

- A new work system[33] will emerge and new roles will be created to replace, supplement or modify current roles in the existing ATM system. Changes to the characteristics of the work system will have consequences, for example with regard to the ability to coordinate between system actors (be they human or machine actors), the timeliness of access to resources and the ability of the work system to adapt.
- Following a total system approach, the new work system must provide new tools to support continuous, system-wide awareness of the status of all critical processing, at all times, including during degraded modes of operation or, for example, cyberattacks.
- New tools must enable humans to make effective decisions, including where collaborative, co-adaptive and joint intelligence modes of decision-making are used (in the controller working position, the cockpit, the ATSEP working position, etc.). In addition, these tools must support capacity for containing cyberattacks and technical failures, ensuring recovery and safety throughout the functional system. The joint work system will need to have explicit objectives that optimise performance and resilience.
- Achieving the SESAR ATM target concept will therefore require a different approach to defining the role of the human from that used in the past. It will be necessary to acknowledge and embrace the interdependence between the various actors in the loop, human and machine, working together in joint activity with shared processes built on an integrated design that optimises the collaboration of actors with a view to optimising system performance.
- The work system design will be based on a systems-thinking approach, according to which optimised system performance stems from fully understanding task distribution and system dynamics. The design will explicitly incorporate requirements for human and machine actors, enabling effective collaborative work across the entire system. The delivery of sustained system performance will also be supported by a design that provides sources of resilience.
- Change management, which is an indispensable component of the development, implementation and in-service life cycle of the SESAR ATM target concept, will be consistently undertaken. It is integral to the successful implementation of large and complex sociotechnical systems, to ensure not only that preparation for transition to a new work system is embraced but also that sociological factors and the needs of all actors involved, including those who will influence and enable organisational change, are taken into account.

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

A.3.2. Changes to address

The following developments are anticipated within the work system:

- the gradual digitalisation of ATM;
- in this context, the changing human role and the changing nature of work carried out by humans, which will emerge from the implementation of the ATM target concept;
- new work relationships and dependencies, as the integrated nature of work evolves.

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

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

- Potential exists for redistribution of tasks and functions between existing system actors (between humans in the system, and between the human and the machine) and new, emerging roles.
- The traditional belief that the human will manage unexpected events unaided or unsupported is no longer viable.
- A new human–machine integrated approach will be utilised to deliver targeted performance in nominal and non-nominal conditions.
- In some cases, responsibilities traditionally attributed to human roles (pilots, ATCOs, ATSEP), including for system maintenance and supervision, will change. This may result in machine actors taking over a number of tasks, for instance when it is not possible for the human to perform any meaningful function.
- Assistance will be provided by new tools to enable human operators to address new challenges such as cybersecurity, new degraded modes or cascade failure effects due to the interdependence and tightly coupled relationship of interoperable ATM/ANS systems.
- The legal implications of human and machine actors sharing tasks, in terms of responsibilities and accountabilities, will be determined at every step change towards the ATM target concept.
- The joint nature of a collaborative work system introduces new factors and behaviours that serve to add complexity and system variability, as each new function may involve differing combinations of human and system elements working together and interacting functionally.
- In particular, for cybersecurity, new tools will be needed to enable actors to distinguish, for all systems, between system failures and cyberattacks.
- Change management will remain an essential element of the critical path for successful implementation of the target concept. In keeping with the systems approach, the scale of collaborative activities will include a broad range of roles, actors and organisations at all levels.
- The skills and knowledge required of human actors – system wide – will be different, generally more managerial and complex, in future. Ongoing competence and capability will be achieved only through integrated continuation training.
- There will be a greater need for in-depth technical training for humans in ATM to address the higher level of complexity of SESAR systems and the need, during a transitional period, for workers to continue to maintain the ability to use legacy systems as long as they remain in operation.
- While change management will be used, social issues may still arise as a result of the redistribution of responsibilities and changes in the business models of ANSP operations within the European ATM system.

A.3.3. Approach to change management

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

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

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

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

- Staff involvement. The effective and active participation and involvement of the European civil and military aviation communities, including trade unions and professional staff organisations, in R & D activities and subsequent deployment activities will be required, to enable proactive identification of social and change management risks and opportunities, with regard to the common goal of improving the overall performance of the ATM system. The involvement of staff and staff representatives in validation activities and simulations (e.g. through the international validation team) will support this goal.
- Social dialogue. Social partners in the European Sectoral Social Dialogue Committee for Civil Aviation must ensure that all affected parties are appropriately represented and must take a proactive and supportive role in ensuring the successful implementation of the SESAR target concept, through stable participation structures and clearly defined mandates.
- Training. Consideration of the effort and costs associated with changes to the role of the human is crucial. This may include training staff, development training, technical training involving staff in simulations and procedure design, training infrastructure development, and operational and technical developments. To avoid a negative impact on staffing and, consequently, on ATM capacity, the effort and cost associated with these activities must be included in business cases related to SESAR deployment.
- Change management. Provisions will be made for effective and optimal change management. This will support a transition path that considers the influence of successive migratory implementation steps towards the agreed concept evolution.

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

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

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

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

A.3.4. Gender equality in air traffic management

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

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

Most organisations today recognise the added value that gender equality and ethnic and cultural diversity bring to organisations. While transforming the European ATM system over the years to come, as described in the Master Plan, all ATM organisations are strongly encouraged to achieve balanced gender participation at all levels of their organisations in line with the European initiative 'Women in Transport – EU Platform for Change'.[34]

A.4 Cybersecurity in a safety-oriented industry

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

The aviation system will evolve significantly in the future, with the application of new operational concepts, an increased use of commercial off-the-shelf products developed using open standards, increased sharing of data and networking of systems, and the introduction of new vehicles into controlled airspace. The next generation of systems resulting from the digitalisation of aviation will apply emerging technologies (e.g. AI[35], data analytics, new security technologies), and may introduce new threat vectors, particularly in the area of cybersecurity, the exploitation of which could result in undesirable impacts on the safety of operations, capacity, delays, cost-efficiency and the environment.

The ACARE strategic R & I agenda supports the realisation of the goals of Flightpath 2050[36]. Safety and security are addressed by five common threads that are equally relevant in the context of the Master Plan:

- collaborate for security: a framework must be in place for system-wide security governance, addressing policy, regulation and oversight, and the application of appropriate security management systems;
- engage personnel and society: the means to develop a security culture must be established and implemented across the aviation industry;
- security intelligence: this will be required to provide the information necessary to effectively identify current threats and vulnerabilities, and to predict and prepare for those emerging in the future;
- operational security: capabilities in incident management must be developed to deliver the means of detecting security incidents in real time, and responding and recovering rapidly;

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

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

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

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

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

OPTICS2 (observation platform for technological and institutional consolidation of research in safety and security) workshops have provided additional insights into research priorities, including the need to:

- develop capabilities in secure information acquisition, storage and dissemination;
- develop system architectures that support the development of secure, resilient systems, capable of rapid adaptation to novel attack vectors;
- develop modelling and simulation tools capable of demonstrating the compliance of a system with security requirements;
- apply intelligent systems to a variety of areas of aviation security (the application of AI to user behaviour analytics, network surveillance or incident forensics, for example, could provide a system with the capability to react autonomously to breaches, adaptively delaying or neutralising ongoing or developing attacks);
- carry out research into the safety assessment and certification of safety-critical systems that incorporate technology based on AI.

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

B. SRIA flagships and their research and innovation needs

The following sections are extracts of the key elements of the Strategic Research and Innovation Agenda (SRIA) that can be found in the SESAR 3 JU website at https://www.sesarju.eu/news/digital-european-sky-sria-latest-draft-now-available

B.1 Connected and automated air traffic management

Europe's ATM infrastructure operates with low levels of automation support and data exchange, leading to rigidity, lack of scalability and resilience, and an inability to exploit emerging digital technologies, including in support of new airspace users. The future architecture of the European sky requires increased automation in air traffic control and an infrastructure commensurate with the performance required by each airspace user type and environment, including those in the transition areas between Europe and neighbouring ICAO regions which may have specific regulations and challenges.

The Digital European Sky vision recognises that the future ATM environment will be increasingly complex, with new airspace vehicles flying at different speeds and altitudes, compared with conventional aircraft. Moreover, there will be increasing pressure to reduce the costs of the ATM infrastructure while improving performance. Secure data-sharing between all the components of the ATM infrastructure and the relevant stakeholders is a key part of the Digital European Sky, together with automation using the shared data to improve ATM performance. This flagship identifies the specific research needed to realise the automation and connectivity vision of the European ATM Master Plan for the future ATM ground system.

Ten R & I needs have been identified in relation to this flagship.

- **Enabling the deployment of a performance-based CNS service offer**. Industrial research and demonstration of an integrated performance-based CNS service offer will be required building on the industrial research on selected technologies (e.g. Satcom, AeroMACS, LDACS, etc.) carried out in SESAR 2020. This unified framework, made up of a backbone infrastructure, supported by a back-up minimum operational network, will maximise cross-domain opportunities and synergies and will support various airspace concepts. The development of non-safety-of-life ATM applications using commercially available services (e.g. 5G, open Satcom) will be required in order to contribute to a hyperconnected ATM system.
- **Advanced separation management (U-space integration and new separation modes)**. Research is required to understand how different modes of separation provision enable interoperable ATM and U-space services to co-exist, considering the diversity of aircraft performance characteristics and DAA capabilities. For separation provided by ANSPs, full sharing of all relevant information between all actors, and fully harmonised trajectory prediction capabilities will allow advanced separation support to be provided to controllers in terms of resolution advisories for human or automatic implementation. Research that will consider predictive modelling and machine learning will contribute to develop advanced modes of separation (e.g. dynamic separation) benefiting from automation and improved connectivity. Formation flying, self-separation between drones themselves or with manned aviation (stay well clear) and pairwise separation are some of the areas of research to be considered in order to adapt to the diversity of traffic in all phases of flight and in all classes of airspace.

- **Intelligent queue management.** Research into additional extended arrival management capabilities is required so that current procedures, focused on transferring predicted arrival holding times from the TMA to the upstream airspace to reduce holding, can evolve towards individual target times for each aircraft. This can be achieved through arrival metering points that take into account the cross-impact of multiple arrival sequences sharing the same airspace (overall network impacts) and ensure optimum use of performance-based navigation arrival routes, enabling aircraft to fly continuous descent approaches from en route through the TMA. This area, including relaying of instructions from ATC to pilots, is a promising one for higher levels of automation as it can be carried out under ATC supervision without impacting separation and sector team management. The efficient strategy and resolution of simultaneous constraints (brokerage function) related to multiple extended arrival management advisories also requires further research. Furthermore, research should consider how larger unmanned aircraft, such as cargo drones, could fit into airport arrival queues, and whether arrival management automation could be extended to possible queues of air taxis approaching a congested air taxi hub. Research into departure queue management automation will also contribute to improvements in uninterrupted aircraft climb profiles from airport to free route airspace. As with arrivals, departure queue management automation is dependent on the exchange of highly accurate trajectory information between all actors (i.e. airport, ANSP, aircraft operator); such techniques are likely to also apply to drones, air taxis and larger unmanned aircraft.
- **Runway use optimisation through integrated use of arrival and departure time-based separation tools.** The most modern time-based separation tools are already good examples of the value of automation in ATM. Research is required to further improve the whole runway usage process, combining arrival and departure capabilities. Data-sharing between airport collaborative decision-making parties, arrival and departure managers and time-based separation tools will allow the dynamic optimisation of the runway(s) based on prevailing operational needs. Such solutions will, for example, choose the most appropriate departing aircraft to make use of an arrival gap, sharing data with the airport systems to ensure that the departing aircraft is loaded and taxies to be in the right place at the right time.
- **Airport automation including runway and surface movement assistance for more predictable ground operations.** Airport ATC will also benefit from further automation support to manage increasing complexity. Further research is required into the automation of stand planning, taxi routing and ground deconfliction, and runway use optimisation, based upon improved and increasingly accurate data-sharing between applications. A holistic view, beyond the integration of airport operations plan (AOP) and a network operations plan (NOP), integrating different technologies and data sources combined with AI / machine learning will bring improvements to ground operations and enable more collaborative decision-making between stakeholders, thus improving predictability and the network performance as a whole.
- **Integration of safety nets (ground and airborne) with the separation management function.** The separation assurance of the future aviation ecosystem will require close conformance monitoring of the negotiated and authorised flight trajectories throughout the execution phase, to be coupled with the advanced defences provided by independent ground-based and airborne safety nets. The use of those trajectories in the progressively more automated detection, classification, resolution and monitoring of conflicting profiles in the planning and tactical phases of ATM will minimise the opportunity for separation to be eroded. However, consideration as to the level of independence of the safety nets from the other aspects of control will be critical as the levels of autonomy of those other systems increase.
- **Role of the human.** The goal of automation is not to replace the human, but to optimise the overall performance of the sociotechnical ATM system and maximise human performance. This will require the development of the role of the human in parallel with ATM concepts and technological developments. New tools are needed to support continuous, system-wide monitoring of all critical processing, including during degraded modes of operation or, for example, cyberattacks. New tools must also enable humans to make effective decisions, including where collaborative, co-adaptive and joint intelligence modes of decision-making are used. A move from executive control to supervisory control will require a thorough understanding of the implications for the humans and their interaction with the systems. The human-to-technology balance is likely to vary between domains: some problems might be solved by automation with little human intervention,

while other areas might require a human, monitored by an automated safety capability, to solve the problem. Research will need to address all the roles, responsibilities and tasks of the different actors (airborne and ground, ATM and U-space, operating and technical); training needs; and change management for the evolving roles as per the recommendations provided by the Expert Group on the Human Dimension of the SES.

- **Speech recognition for increased safety and reduced workload.** Voice communications between ATCOs and pilots are still not digitalised, and are therefore not readily accessible for machine analysis other than through analogue voice-recording analyses. While data communication or text-based transmission of data between ATCOs and pilots is envisaged to supplement radio communications in future operating environments, this capability is unlikely to replace radio communications completely in the near term. Therefore, R & D of a data-driven (machine learning-oriented), reliable, error-resilient, affordable and adaptable solution to transcribe automatically the voice commands issued by ATCOs and its read-back confirmation provided by pilots is of high importance. The digitisation of controller and pilot voice utterances can be used for a wide variety of safety and performance-related benefits, such as pilot read-back error detection, pre populating electronic flight strips and other tools using automatic speech recognition, estimating controller workload using digitised voice recordings, or anticipating ATCO actions and behaviour. This will greatly improve safety and reduce controller and pilot workload. Other potential uses of speech recognition could include the adaptation of ATM systems. Further pilot-centric applications are also identified in Annex B, Section B.2, below.
- **Network-wide synchronisation of trajectory information.** Providing trajectory advice (including uncertainty considerations and improved weather forecasts) to ATCOs for human confirmation or automatic implementation is essential for the realisation of the vision. While optimising cost and minimising environmental impact, this trajectory advice will not only assure separation, but also address all other operational constraints, considering ad hoc downstream and pilot requests or non-conformance, continuous descent and arrival management demands, downstream airspace availability and workload, AO business needs and equity, the evolution of certainty over the prediction horizon, ATCO preferences and ensuring workflow integration, redundancy and safe degradation. An implementation-ready maturity gate is foreseen for 2023 to verify whether full deployment of the currently researched interoperability solution is realistic within the Horizon Europe time frame. Integration of this solution, if mature enough, in the digital sky demonstrator network will make it possible to accelerate its deployment. Alternatively, R & I activities could be required to find alternative solutions to support the pressing need for synchronised trajectory information in the network. The applicability of the current solution, or of any alternative, with the foreseen introduction of ADSPs will also need to be investigated to ensure a service-based and cost-efficient way forward. Additional research is needed concerning the network-centric flight data exchanges to ensure the network synchronisation of trajectory data and provision of required flight data by different stakeholders during the flight planning and execution phases.
- **SWIM.** SWIM implementation will be a key enabler in the achievement of global interoperability for data-sharing and leveraging hyperconnectivity in conjunction with the future communications infrastructure. Implementation activities will focus on completing the development, standardisation and implementation of the various SWIM profiles, in addition to a constant monitoring of stakeholder needs, to ensure the appropriate definition of new SWIM services to further speed up their deployment based on clear use-cases in line with the ADSP requirements. In addition, future seamless integration of ATM and U-space domains via SWIM (e.g. through the yellow profile) requires R & I actions in support of the provision of different services such as registration and identification, dynamic airspace information and geofencing, flight planning and surveillance data.

B.2 Air–ground integration and autonomy

Current ATM systems and technologies are not designed to allow the accommodation or full integration of an increasing number of new forms of mobility and air vehicles which have have a high degree of autonomy and use digital means of communication and navigation. The future ATM needs to evolve, by exploiting existing technologies as much as possible, and developing new ones in order to increase global ATM performance in terms of capacity, operational efficiency and accommodation of new and/or more autonomous air vehicles, that is supporting the evolving demand in terms of diversity and complexity from VLL airspace to high-level operations. This progressive move towards autonomous flying, enabled by self-piloting technologies, requires closer integration and advanced means of communication between vehicle and infrastructure capabilities so that the infrastructure can act as a digital twin of the aircraft. Ultimately, manned and UAVs should operate in a seamless and safe environment using common infrastructure and services supporting a common concept of TBO. Future operations should therefore rely on direct interactions between air and ground automation, with the human role focused on strategic decision-making while monitoring automation.

Seven R & I needs have been identified in relation to this flagship.

- **Enabling greater ground and airborne integration and wider performance.** Greater air–ground integration will require solid, safe and secure means of communication and networking to transform, in a stepped approach, the current way to communicate. From gate to gate, air-to-ground automation will ensure the use of automatic selection of the link for and frequency of communications by the pilot and ATC. This will support SPO and cross-border operations. Air-to-air communication will enable new operations (formation flights, etc.) and will support advanced separation management and safety nets in the context of the safe cohabitation of different types of air vehicles (high altitude, drones, airplanes, helicopters, etc.). Satellite-based technologies can speed up global deployment for other technologies through virtualisation of infrastructures and synchronised deployments for all stakeholders. Research is required to integrate these technologies into a multilink environment that supports the interoperability and hyperconnectivity of air–ground communication, as well as the transition to internet protocol (IP)-based communications.
- **Integrated 4D trajectory automation in support of TBO.** A common 4D trajectory, shared between every application that needs to process each flight, and updated by every application acting upon that flight, underpins ground-provided ATM. The accuracy of the trajectory is likely to improve at every stage of flight planning and execution. This requires earlier access to / sharing of detailed flight planning information, and all subsequent updates; publication of planning adjustments to the trajectory; and, subsequently, ATM trajectory adjustments, correlated with the aircraft's actual trajectory. These principles also apply to new airspace users, including drones, air taxis and high-altitude vehicles. The integration/revisions of 4D trajectories will be based on the extended flight plan exchanges and will require different 'flight and flow information for a collaborative environment' services in the pre-departure and post-departure phases of flight, including the exchanges of planned 4D trajectory. The extended flight plan revisions during the planning and execution phase requires further research. Implementation of the TBO concept and flight and flow information for a collaborative environment needs to consider all the different parts that have to be developed in a synchronised way and, as soon as integrated, can offer the relevant services to the airspace users. Besides controller–pilot data-link communications and human-to-human communication, data link will also support machine-to-machine communication, enabling the integration of extended projected profile within the network manager system and further steps in 4D trajectory operations on the path towards ATM/U-space convergence.
- **Complex digital clearances.** Industrial research activities will finalise the development of ground systems to enable complex digital clearances, taking into account traffic synchronisation, demand- and capacity-balancing and conflict management. In particular, after having implemented the initial concept of 4D trajectories via the sharing of trajectory (air to ground), there will be a need to go a step further on a larger scale thanks to controller–pilot data-link communications exchanges (ATN Baseline 2 improved clearances and instructions).

- **ATM/U-space convergence.** The goal here is to define the TBO concept and requirements for drones to operate in U-space, interoperable with TBO in ATM. This concept is necessary to facilitate their access and operations in controlled airspace, and requires the development of separation standards for drones/drones and drones/manned aircraft, supported by procedures and performance-based requirements. In addition, there is a need to identify requirements for a U-space secured digital backbone that is interoperable with SWIM. The specificity of drones on account of their remote control has to be explored, identifying, for both nominal and emergency conditions, the way in which TBO and appropriate connectivity to SWIM can be safely assured, while also taking into account the ground system and associated operational procedures.
- **SPO.** A significant move from current aircraft with two pilots to a single crew in the cockpit (i.e. SPO) is being investigated. SPO, as opposed to fully automated flight, respects the societal expectations to have a human in the cockpit for strategic decision-making while increased automation enables automatic flight phases. A precondition for success is the ability to have a demonstrator by the end of 2027, in close cooperation with EASA. In order to operate safely with a reduced crew, safety systems and crew health monitoring systems will be a key enabler to trigger the back-up modes in case of incapacitation, stress or exhaustion of crew members. This is of paramount importance in order to be able to recognise possible dangerous situations, forgotten steps of procedures or check lists, or inappropriate or non-executed actions by the pilot. There is a need to demonstrate the integration of a safety-critical autonomy platform, with an extended high-integrity flight control platform hosting time and safety-critical functions, as well as flight control utilities and autonomous back-up mode, which will be developed outside this SRIA (e.g. Clean Aviation, CORAC). Following an assessment of the roles of ground and air actors, both in normal and abnormal conditions, in the context of SPO supported by a digital assistant, the following topics should be addressed:
  - safe return to land: conditions under which pilot incapacitation is declared and how it is handled by the various actors involved, definition of ground assistant role when the pilot is in command, the definition of incapacitation declaration and management procedures between aircraft, the airline operation centre and ATM;
  - flight operations centre–wing operations centre / ATC connectivity: the expected role of a flight operations centre / wing operations centre in the case of SPO abnormal situations requires their connection to ATC centres to support safe return to land even in a congested traffic environment.
- **Integration of drones in all classes of airspace.** The Digital European Sky builds on the evolution of ATM towards the integration of drones, from small vehicles that are operating mainly at VLL close to urban areas and airports, up to large vehicles, such as RPAS, used both for civil and military applications, which will routinely operate safely using ATM services: manned and unmanned should be able to use the same airport infrastructure; they will both communicate with ATC using data link; rules and procedures will be applied to both, with some adaptations for drones as the pilot is on the ground. The research will look at:
  - how to enable drones to operate in controlled/uncontrolled airspace, under both IFR and visual flight rules, and safely integrate with cooperative and non-cooperative traffic;
  - how to ensure that airborne safety nets will remain effective and independent from separation provision, while possibly adapting ground-based safety nets to these new modes of separation.
- **Super-high-altitude operating aerial vehicles.** These vehicles, which can be viewed as drones, will also need to be integrated, with entry and exit procedures through segregated or non-segregated airspace. As a result, new airspace users include highly autonomous vehicles. Safe separation management of this traffic and efficient integration into the traditional ATM operation is both a technical and operational challenge. Moreover, airborne surveillance and the safety nets (terrain, weather, traffic) and evasive manoeuvres will certainly be impacted by the introduction of new vehicles, such as drones (evolving in lower airspace below 500 ft.).

B.3 Capacity on demand and dynamic airspace

For the last few decades, capacity has not been available when and where needed, and it has often been available when and where not needed. The number of new airspace users, including RPAS/HAO traffic, will increase by 2030 and will require an increased level of capacity and of variability in that capacity. Integrated ATM requires agility and flexibility in providing capacity where and when it is needed, particularly for maximising the use and performance of limited resources, that is airspace and ATCOs. It will require the dynamic reconfiguration of resources and new capacity-on-demand services to maintain safe, resilient, smooth and efficient air transport operations while allowing for the optimisation of trajectories even at busy periods.

Three R & I needs have been identified in relation to this flagship.

- **On-demand ATS.** In the future, the increasing number of flights and emerging new technologies will lead to a structural transformation in the way ATS are provided. Delivering the capacity needed across the network and improving cost and flight efficiency, while maintaining safety and resilience, requires the supply to be optimised on demand in a dynamic, agile and resilient manner. The challenges of providing capacity on demand are as follows.
    - Ensuring that automation using AI supports ATCOs and is under their supervision.
    - Adapting training programmes for ATCOs and other ATM personnel in order to manage an increased level of automation. The management style should ensure the transparency of automated processes to humans and the capability of human interventions only when necessary.
    - Addressing legislation, certification and social dialogue issues.
    - Offering an increased level of capacity, while accepting a much higher level of complexity so that optimised flight-efficient trajectories do not result in structural limitations on capacity.
    - Offering increased levels of capacity and flexibility to allow capacity variations in time and space to meet levels of demand.
    - At all times offering airspace users the most environmentally friendly options when there is the need to constrain traffic, particularly when queueing aircraft at the arrival or departing runways – so that holding no longer exists as part of normal operations and, if and when there is the need for conflict resolutions, offering real-time options to airspace users so that they can select the least penalising trajectory.
    - Establishing a network performance cockpit for 'network minded' decision-making, including support for enhanced connectivity both for identifying unattended business opportunities and for managing disruptive crises.
- The capacity-on-demand concept aims to flexibly allocate resources to where they are required due to traffic demand, irrespective of the controller's physical location in Europe, while taking into account network optimisation needs. It also requires standardised data-sharing between ATS providers using a highly interconnected and resilient network.
    - Dynamic airspace management and dynamic airspace configurations (DACs): improvement of airspace utilisation is obtained through flexibility in airspace organisation and design, and flexibility and agility in airspace management. DACs are used to accommodate specific civil and military demands. DACs' integration into ATFCM will contribute to the collaborative optimisation of traffic flows. Airspace management configuration should accommodate traffic demand and military operations, thereby resolving complexity issues, balancing workload and optimising resources, using digital services (e.g. machine learning to identify and exploit information patterns, and AI to identify and design new elementary basic sector volumes). Potential changes to ATCO licences and training will need to be researched, including the use of conflict detection and resolution support tools by ATCOs in order to ensure capacity growth, against a trend of creating smaller sectors where capacity benefits reach a finite limit. The challenge for DAC is to join airspace management and ATFCM into a single 'rolling' planning process, while optimising airspace resource utilisation and fully linking to performance targets.

- Dynamic mobile areas (DMAs 2 and 3): DMAs will support the dynamic configuration of segregated airspace and the management of mission trajectories, thus contributing to the efficiency of both civil and military operations. The areas will have a potential to 'roll over' following use over time, distance and volume as a mission progresses, allowing for the early release of airspace for other users.
- Dynamic extended TMA (including procedures and systems to enable continuous climb operations and continuous descent operations): TMA operations will benefit from the capability to dynamically extend the scope of terminal airspace, bringing improved flight efficiency. This will further optimise the application of advanced continuous climb and descent operations and will improve descent and climb and the synchronisation of arrival/departure flows.
- Flow-centric approach including the full reconciliation of ATFCM measures with other measures/advisories and with the multiple constraint manager: network operations will be further enhanced by the optimisation of multiple ATFCM demand measures while reducing the adverse impact of multiple regulations affecting the same flight or flows. Indeed, for the provision of common network situation awareness and enhanced demand- and capacity-balancing, network management will gradually evolve towards flow-centric operations. This will enable a collaborative approach in the context of flow and network management for increased dynamic capabilities and predictability, leading to the capacity-on-demand concept.
- Digital integrated network management and ATC planning (INAP): in order to cover the planning gap between ATFCM and ATC processes and to facilitate layered ATM planning in the execution phase, INAP will be gradually implemented to optimise the flow management process. Digital platforms would aim to expand the what-else concept, for example the system suggests alternatives or refinements based on the initial solution proposal by the operator. AI and automation is still to be researched while the INAP CONOPS is already clear now. Within INAP, there is also the need to research spot management, which uses traffic monitoring values, standing for different objectives (safety, rate optimisation, critical and crisis situations, etc.) to define and address different types of spots (regions of interest). For instance, local spots need to be integrated (in terms of information-sharing and operational procedures) with the network manager's NetSpot.
- The network integration of HAO (FL500 and above): there is a need to ensure the integration of these operations as they transit through the classic European ATM network. Indeed, the current network and higher airspace should be seen as a continuum requiring research, and eventually demonstrations, to confirm the services required by new airspace users, notably high-altitude long-endurance platforms; suborbital and commercial space operations; and supersonic, and eventually hypersonic, passenger transport. Challenges exist in how to integrate new entrants with their diverse performance transiting through the classical ATM network, as well as in determining the services required in HAO. Moreover, these HAO challenges and services' definition require extra-European coordination. Some examples are as follows:
  - to transform some European airports into spaceports (designated and authorised site for launch/take-off and/or re-entry/landing of suborbital vehicles);
  - the use of non-cooperative tracking of a high-altitude vehicle: it could be continuously carried out in real time in order to monitor the vehicle's status, to monitor the flight path and to enable the prediction of the vehicle's position, or debris excursion in the case of a mishap.
  - RPAS demonstration for RPAS accommodation in controlled airspace (airspace classes A–C): this key R & I activity aims to accommodate IFR RPAS in non-segregated airspace in accordance with the drone roadmap in the European ATM Master Plan. The objective is to enable IFR RPAS operating from dedicated airfields to routinely operate in airspace classes A–C as general air traffic without a chase plane escort. The scope includes development of adaptations to the flight planning processes, demand- and capacity-balancing developments, contingency, etc.

- **ATM continuity of service despite disruption.** The new airspace architecture should enable solutions allowing for continuity of service in the case of disruption. For example, it should enable resources (including data) to be shared across the network, supporting flexible and seamless civil/military coordination and allowing for more scalable and resilient service delivery to all airspace users. Resilient ATM systems would continue to provide services despite disruption, for example during capacity bottlenecks, adverse weather, national system breakdowns or disruptive social actions.

- Reconfiguration/consolidation of x-border dynamic and remote ATS: operational plans need to include flexible and dynamic sectorisation by taking into account basic complexity indicators based on specific shapes of demand, network flight-efficiency needs plus existing ATC technology-enabled capabilities and the application of the virtual centre concept. A new notion of area control centres with multiple areas of responsibility will provide remote ATS capability. This can lead to the need for local/regional plans for cross-border sectorisation and consolidation/reconfiguration, in particular for the upper airspace sectors, in a dynamic manner.
- Training and licensing of ATCOs: an assessment is required of the level of new training and licensing needed for new cross-border dynamic sectors and remote ATS operations where sector families or traffic flows may be new to ATCOs.
- Training and competency requirements for ATM personnel contributing to the cross-border ATM/ANS service delivery as enablers of technical reconfiguration for remote ATS operations.

- **Future data services and applications for airport and network.** Future data services and applications commence with a UDPP, which provides airspace users with more control over the selection of flights that are delayed in order to prioritise them based on business needs, and which can gradually be extended to new ATFCM rules and queueing techniques.
  - Integrated UDPP (including links with ATFCM slot-swapping) will demonstrate the application of airspace user priorities and preferences in the establishment of ATFCM measures and support to airspace users to ensure the maximum throughput of payload factor when subject to heavy flow management restrictions and in a crisis period (e.g. terminal overloaded with passengers during periods of dramatic airport capacity reduction). Furthermore, the demonstration of UDPP's concept applicability to other operational environments in the planning phase (en route constraints, use in nominal situations, etc.) is required.
  - In terms of development, support to airspace users is required on the definition and validation of new operational and social indicators. These should be integrated into the overall R & I performance framework, building on the results of SESAR validations, identification of gaps and development of steps from research to pre industrialisation and deployment (full integration of operational processes and systems' interoperability).
  - The integration of connectivity within the loop of ATM operations, the new data sets available through airport collaborative decision-making, UDPP, AOP/NOP data, target time over / target time arrival and extended arrival management demand further development of the rules for ATFCM and queuing priorities. This will require further exploratory research.

Demonstrations are expected to play a critical role in closing the industrialisation gap, as they can potentially act as a platform that accelerates the creation of a critical mass of early movers to complete pre-implementation activities, maximising the chances of speeding up the time to market and operational uptake throughout the network.

B.4 U-space and urban air mobility

Over the next 10 years, the implementation of this SRIA aims to unlock the potential of the drone economy and enable UAM on a wide scale. To that end, a new ATM concept for low altitude operations needs to be put in place to cater safely for the unprecedented complexity and high volume of the operations that are expected. This concept, referred to as U-space, will include new digital services and operational procedures and its development has already started within the SESAR 2020 programme. U-space is expected to provide the means to manage, safely and efficiently, high-density traffic at low altitudes involving heterogeneous vehicles (small UAVs, eVTOL aircraft and conventional manned aircraft), including operations over populated areas and within controlled airspace. U-space will have to integrate seamlessly with the ATM system to ensure safe and fair access to airspace for all airspace users, including UAM flights departing from airports. The development of U-space will have to overcome extraordinary challenges. A new regulatory framework, supported by a comprehensive set of standards, has to be established to provide a solid framework for safety and interoperability without hindering innovation. U-space will have to integrate seamlessly with the ATM system to ensure safe and fair access to airspace for all airspace users. This integration will not be straightforward since the requirements on U-space services may not be compatible with those imposed on ATM. To cater for the anticipated volume of operations, U-space will need to rely heavily on automation and to take advantage effectively of emerging on-board capabilities and advanced digital technologies on the ground. In addition, U-space is expected to have a profound socioeconomic impact, enabling the creation of a new marketplace for U-space service provision and accelerating the advent of the drone and UAM economy. Ultimately, the development and deployment of U-space will help position Europe as the global leader in UAM and drone-based services, accelerating the development and adoption of new technologies (AI, cloud, digital services, big data) and fostering the creation of high-quality jobs.

U-space provides an unparalleled opportunity to experiment, test and validate some of the key architectural principles and technology enablers of the future Digital European Sky before incorporating them into the broader ATM ecosystem. It can potentially help de-risk and accelerate the digital transformation of the European ATM system while opening the way to the safe integration of new vehicles into the airspace. UAM is expected to be the most challenging type of operations supported by U-space. UAM will enable on-demand highly automated operations of drones and larger eVTOL vehicles over urban areas, providing cargo, emergency and passenger transportation. Plans are afoot to deploy UAM in many European cities, with small-scale cargo operations already taking place and initial passenger services expected to launch by 2025. UAM will involve new types of vehicles with heterogeneous performances and high levels of autonomy, which will have to coexist with conventional manned traffic and will need to be accommodated by the U-space and ATM ecosystems.

Considering the above, the main R & I challenges required to deploy U-space will include the following 12 R & I needs that have been identified in relation to this flagship.

- **Mature, validate and deploy across Europe the basic U-space services.** The set of U-space services has been divided into four levels (U1–U4) of increasing sophistication and complexity: U1, which includes services such as registration, remote identification and geofencing; U2, which encompasses services such as flight planning, flight approval, tracking and the interface with conventional ATC; U3, with advanced services supporting more complex operations in dense areas, such as traffic prediction and capacity management, as well as assistance for conflict detection and resolution (automated DAA functionalities); and U4, with services still to be defined that will support high levels of autonomy and connectivity, as well as integration with manned aviation and ATM.
- Although descriptions of many services exist at U1, U2 and even U3 levels, and a CONOPS shows how they can fit together, work is still needed on validation, cost–benefit analysis and standardisation. Although different U-space architectures have been proposed, work is still required to assess different options and identify those that meet the full range of requirements by the different types of operations and that guarantee safe and secure interoperability, thereby enabling a pan-European competitive environment for the provision of U-space services. One of

the challenges is to enable the simultaneous operations of multiple USSPs in the same airspace. In addition to the definition of potential U-space architectures, preliminary implementations of U1 and U2 services have already been demonstrated in the SESAR 2020 programme. Eurocontrol is collecting data from States to assess their progress towards deployment (as part of the EU network of U-space demonstrators' initiative, led by the European Commission), which has so far been limited. Many questions still need to be answered before full-scale deployment is feasible, particularly in the areas of interoperability, certification and performance requirements, safety and security, fairness, contingency management, financing and liability.

- **Develop advanced U-space services.** In parallel with the full validation, industrialisation and deployment of the basic U-space services, work needs to start on the definition, design and development of advanced services. The most advanced U-space services (U3/U4) will enable UAM missions in high-density and high-complexity areas. The required technologies to enable performance-based CNS services in U-space need to be identified and assessed in operational environments. For example, the use of mobile communication technology, such as 5G, and other emerging technologies for connectivity should be studied, as well as data-link solutions to enable electronic conspicuity and surveillance. Different solutions for separation management for all types of vehicles in all types of airspace (including airborne DAA, as well as ground-based and hybrid, solutions) should also be considered.
- **Enable urban Air Mobility (UAM).** The requirements of UAM operations are expected to be the most challenging for the U-space ecosystem. One of the key research questions is how to integrate the airspace autonomous operations over populated areas safely into complex and congested airspace environments, with operations involving vehicles interacting with U-space and conventional ATM services. Research should investigate how U-space can support the transition from piloted to autonomous operations (linked to EASA AI Regulatory Roadmap37). The evolution of U-space together with its associated regulatory framework and standards will need to be synchronised and coordinated with the development of the future UAM ConOps, its associated UAM services and the certification of UAM vehicles. Special consideration should be given to the operational limitations of these new vehicles and how U-space can contribute to operational safety by protecting their operation in contingency and non-nominal situations. In addition, mechanisms and protocols to enable Collaborative Decision Making in the context of UAM, involving ATM, U-space and city stakeholders, will need to be explored.
- **ATM/U-space integration.** U-space services should enable safe and efficient operations of unmanned aircraft without negatively impacting the operations of other airspace users. The seamless integration of U-space and ATM services is expected to contribute to the fairness, safety, efficiency and environmental impact of the overall air traffic system. The capacity benefits and flexibility of an airspace without segregation requires the full integration of U-space and ATM. For U-space and ATM environments to be integrated, it does not necessarily mean they operate in the same way. They could be very different indeed, but with suitable interfaces to allow safe and effective coexistence. Standard operating procedures will need to be defined (e.g. rules of the air and airspace management) to allow manned and unmanned aircraft to share the same airspace safely, as well as the simultaneous provision of U-space and ATM services). The safety, security, certification and regulatory challenges arising from the provision of U-space services to manned aircraft should be studied. Information exchange will be critical to enable a safe convergence of U-space and ATM. Challenges include cybersecurity, data compatibility and the reconciliation of different standards and certification requirements. Another critical aspect of the integration will be the role of the human, particularly regarding the high level of automation that will be delivered by U-space services and the automation disparity between ATM and U-space.
- In addition to the key challenges described above, the following transversal research areas will be critical to the successful development and deployment of U-space.
- **Financial and legal aspects.** Research needs to be conducted on potential U-space and drone operator business models, focusing on the mechanisms required to create a fair and competitive U-space market across Europe. The available alternatives for the financing of a sustainable

[37] Artificial Intelligence Roadmap, A human-centric approach to AI in aviation", version 1.0, European Union Aviation Safety Agency, February 2020

U-space ecosystem should be analysed, including how to optimise public and private investments and the implications for the financial model of European ANSPs. The insurance models required for U-space should also be analysed.

- **Social acceptance.** Work is required to ensure that the new operations enabled by U-space are acceptable to the public. Specific areas of concern will be UAM noise, visual pollution, privacy, etc. In addition, a consensus must be reached on the acceptable target level of safety of the different types of operations under U-space. The impact on general and leisure aviation should also be considered.
- **CNS and separation minima.** Work is required on the definition and validation of performance-driven CNS requirements for operations under U-space, together with the applicable separation minima. The separation minima will be related to the CNS performance, available separation management services and other relevant criteria – ground risk, vehicle performance, etc. The validation of CNS technologies against the performance criteria will be required.
- **Support the development of the U-space regulatory framework and required standards.** Leverage extensive modelling, simulation and experimentation to assess the maturity and interoperability of U-space services, assess different deployment options and support their industrialisation and deployment. Create U-space test centres offering an environment for stakeholders to conduct reproducible and interoperable tests in conditions comparable to live operational scenarios, with the objective of validating standards and regulations in representative environments. Such centres can also support the certification of new USSPs, services or technologies, making it possible to increase flexibility for rapid and agile increments of the U-space ecosystem.
- **Transfer of U-space automation technology to ATM.** Explore whether U-space can be an accelerator of the ATM innovation life cycle, facilitating faster, lower-risk adoption of new technologies or approaches (automation, AI, cloud, etc.).
- **U-space performance framework.** A performance framework for U-space needs to be defined in concordance with the overall SES performance framework, so as to assess and guide the deployment process based on objective and quantifiable performance measurements.
- **Safety assurance.** New safety modelling and assessment methodologies applicable to U-space are needed. Tools are required to analyse and quantify the level of safety of U-space operations involving high levels of automation and autonomy, where multiple actors automatically make complex, interrelated decisions under uncertainty (e.g. weather-related uncertainty). Research is needed to ensure that the distributed decision-making protocols implemented in U-space achieve the required level of safety while catering for differing levels of experience of participants. Examples of approaches that could be leveraged for this purpose include greater use of simulation and machine learning applications such as stress-testing.
- **Applications above VLL airspace.** Explore potential applications and extensions of U-space concepts beyond VLL airspace, for example to support manned traffic in uncontrolled airspace or to enable high-altitude operations.

B.5 Virtualisation and cybersecure data-sharing

The Airspace Architecture Study clearly highlighted the lack of flexibility in the sector configuration capabilities at pan-European level. This is caused by the close coupling of ATM service provision to the ATS systems and operational procedures, preventing air traffic from making use of cloud-based data service provision. A more flexible use of external data services, considering data properties and access rights, would allow the infrastructure to be rationalised, reducing the related costs. It will enable data-sharing, foster a more dynamic airspace management and ATM service provision, allowing ATS units to improve capacity in portions of airspace where traffic demand exceeds the available capacity. Furthermore, it offers options for the contingency of operations and the resilience of ATM service provision.

The following six R & I needs have been identified in relation to this flagship.

- **Future data-sharing service delivery model.** Data-sharing supports the progressive shift to a new service delivery model for ATM data, through the establishment of dedicated ADSPs. A common EU-wide ATM data service layer will enable all ATM service providers to benefit from the cross-border sharing of data. The ADSP would provide the data and specific applications (e.g. STCA, Correlation, etc.) required to provide ATM services. On the data side, the ADSP will convey CNS (e.g. radar data, flight data processing information), ATM, voice data, AIM data (static, semi-static and dynamic data) and also meteorology (MET) data. The data can be delivered in raw format or be processed to allow the delivery of services such as flight correlation, trajectory prediction, conflict detection and conflict resolution and arrival management planning and will extend to the provision of safety-net services (e.g. short-term conflict alerts – STCA, minimum safe altitude warning – MSAW, area proximity warning – APW) and on decision-making support tools as a service (providing the what-if and the what-else functions, attention guidance, etc.). At a detailed operational and technical level, the question of drawing a clear boundary between ATM services and ADS is open and will be tested through simulations and impact assessments as the concepts mature.
- **Infrastructure as a service.** Through a service-oriented architecture (SOA), the infrastructure services (e.g. CNS) will be specified through contractual relationships between customers and providers with clearly defined European-wide harmonised service-level agreements. This approach will create business opportunities for affordable services with a strong incentive for service providers to rationalise and harmonise their own infrastructure in support of nominal and contingency operations and more generally the provision of safe, efficient, cost-efficient, interoperable and standardised ATM and CNS services. A large part of the CNS services will be provided through applications using space-based sensors. With regard to communications, the transition to- wards an IP-based environment will enable the location-independent transmission of data and/or voice. Possibly, a dynamic allocation of IP connections will reduce the need for VHF channels on the ground side and the need for the airborne side to switch frequencies several times during the flight. R & I needs to deliver solutions utilising infrastructure (CNS, IT, U-space, etc.) as a service, enabling new combined services.
- **Scalability and resilience.** Open architecture guarantees the long-term upgradability and scalability of ATM service provision and the agility required to enhance services. With the delivery of ATM services irrespective of physical infrastructure or geographical location, the defragmentation of European skies can be realised through virtualisation: i.e. decoupling the provision of ATM data services from ATS, allowing them to be provided from geographically decoupled locations. Airspace capacity can be offered on demand through horizontal collaboration between the network manager and the ATS unit. The Digital European Sky will allow for more efficient and flexible use of resources, substantially improving the cost-efficiency of service provision and delivering the capacity needed. Ultimately, the virtualisation of ATM services will allow the creation of new business models and the emergence of new ATM players, which will foster competition in the sector. Importantly, this will enable ANSPs to make implementation choices on how new ATM services are provided. On the other hand, virtualisation will increase the need for a robust and well-proven approach to cyber-resilience, including the skills and means for all human actors in the value chain to detect, respond to, and recover from complex degradation

situations. The increased flexibility of the European airspace through a Dynamic Airspace Configuration makes it possible for an ATSP to cover multiple areas of responsibility through remote ATS unit provision.

- **Free flow of data among trusted users across borders.** The sharing of data through interoperable platforms and, the exchange of open data between trusted partners, combined with open architecture policies, will allow improved collaboration between the different actors and the optimisation of services and processes for all partners in the aviation value chain. Such data exchange should occur on established concepts such as SWIM and consider the associated cyber-resilience aspects. Data will be even more critical in future and not only data-sharing but also proper data structure and storage will have to be provided. On the network level and on the local ATM side, this will allow for big data analytics, which will pave the way for future more efficient ATM operations, thereby optimising the network at strategic level. By applying business intelligence (BI), the network could be organised in a more efficient and stable manner.
- **Regulations and standards.** The implementation of a SOA will have an impact on the management of performance, while potentially significantly improving capacity and cost-efficiency. For this reason, the regulatory environment will need to be adapted to make way for the new ATM Service environment and must facilitate greater consideration of operating expense (OPEX) and lower capital expense (CAPEX) requirements. The charging and cost-recovery mechanisms will need to be more flexible and, on the standardisation side, common formats and exchange profiles will need to be identified to allow a supplier-independent service provision scheme.
- **Cyber-resilience.** The increase in the number of connected devices, data-sharing and common standards will lead to an increase in vulnerabilities, threats, emerging risks and the possibility of cyberattacks. Furthermore, the threat landscape is continually changing, and new attack vectors are created at an equally fast pace. The emergence of new actors, able to disrupt or destroy critical infrastructure, presents a significant challenge for increasingly interconnected and data-reliant industries such as ATM. The need for the efficient application of standards addressing safety, privacy and cyber-resilience risks is obvious to ensure the protection of information and information systems, manage cyber-resilience risks, implement appropriate safeguards to ensure the delivery of services, identify the occurrence and continuous monitoring of cyber-resilience events, and respond to and recover from potential cyberattacks with a proper level of reactivity. It will also be necessary to further develop cyber-resilience guidelines and procedures for ATM, based on existing on existing guidelines and procedures from other domains (e.g. system design principles, cryptography, block chain, software-defined networking). Inclusion of specific techniques already established in other domains should be included (e.g. Blockchain). The context of the cyber-resilience needs to be focused on a pro-active approach to the network. If the resilience remains reactive, any successful attack could lay down large parts of the EU airspace.

B.6 Multimodality and passenger experience

Flightpath 2050[38], Europe's long-term vision document on aviation research, has set the goal that 90% of travellers within Europe should be able to complete their journey, door-to-door (D2D), within 4 hours by 2050. Optimising D2D mobility for people and goods is essential in meeting citizens' expectations for increasingly seamless mobility, where they can rely on the predictability of every planned door-to-door journey and can choose how to optimise it (shortest travel time, least cost, minimal environmental impact, etc.). The role of ATM in the door-to-door chain of a passenger's journey may seem small, but the punctuality of flights, and passengers' perception of flying, is highly dependent on the smooth functioning of the entire journey. This SRIA will, therefore, lead to an improved passenger experience by supporting an integrated transport system.

A significant portion of the planned D2D journey time is taken up by the buffers needed to absorb uncertainties associated with the performance of the various modes contributing to a journey (including within the airports). Mobility providers need access to reliable planning and real-time information on schedules to give more accurate forecasts of arrival and transfer times. Optimising D2D mobility for people and goods is essential in meeting citizens' expectations for increasingly seamless mobility, where they can rely on the predictability of every planned D2D journey and can choose how to optimise it (shortest travel time, least cost, minimal environmental impact, etc.). Considering ATM to be an integrated part of an intermodal transport system will make it possible to share data between modes and to collaborate better to optimise the performance of both the overall transport system and the D2D journey.

The following four R & I needs have been identified in relation to this flagship.

- **Access to / exit from the airport.** Airports are obvious multimodal nodes for aviation real-time information exchange; giving stakeholders (including mobility providers) an increased knowledge of the entire multimodal journey will enhance the reliability of multimodal journey planning, allowing stakeholders to identify potential access issues that could affect the punctuality of operations, alleviate congestion, mitigate regulatory constraints, etc. This, with the extended integration of ATM network planning (multi slot-swapping, aircraft operator-driven prioritisation processes, etc.) and cooperation on enhanced collaborative airport performance planning and monitoring, will enable passengers to have a full picture of their journey and optimise their D2D journey time.
- The concept of airport collaborative decision-making has proven the benefits of sharing information and procedures between airport stakeholders and the wider ATM network. The concept of airport collaborative decision-making will be extended to encompass specific stakeholder information requirements relating to elements of the multimodal journey and fully included in the AOP and NOP collaborative processes.
- Understanding passenger origin–destinations will ensure easy access/egress for all passengers (not only those from the nearby city) and optimal landside and airside design. Use of AI will help optimise pre screening of passengers and departure/arrival queues/sequences in order to accommodate as many D2D journeys as possible. Single ticketing and remote check-in / bag drop will enable smooth transit and easier planning of the passenger journey. Mobility as a service will help with this planning and provide alternative routings in the case of disruption. This will require seamless integration between ATM, UAM and surface transport. The integration of vertiports into airport operations and city surface transport networks will allow the rapid transfer of some passengers right to the heart of an airport using UAS/UAM and facilitate the introduction of point-to-point interurban UAS/UAM flights. This SRIA targets demonstrating such integration through at least one operational implementation in a European city before 2027.

[38] "Flightpath 2050, Europe's Vision for Aviation", Report of the High Level Group on Aviation Research, 2011, European Union

- **Passenger experience at the airport.** Smart airports, with landside and groundside fully integrated into the ATM network, will be based around connectivity and other technologies to improve operations and the user experience. The integration of airport and network planning and the timely exchange of surface network, airport and ATM network information will bring common situational awareness and improved mobility planning activities, notably arrival and departure predictability for both airports and the network. Information-sharing and collaborative decision-making will allow the inclusion of outputs from landside processes (passenger and baggage) to be used to improve the accuracy and predictability of airside operations. Business intelligence and machine learning will help airport stakeholders collaborate to align process and resource capacity with predicted demand to reduce queues. Airport design should favour optimised intra-airport flow; reduced queuing for airport services (check-in, bag scan, immigration, bag reclaim, etc.) and reduced walking distance for passengers; fast and efficient boarding and disembarkation; and should allow passengers to spend buffer time usefully, enjoyably and comfortably, for either leisure or work.
- Drivers for this will include the digital evolution of integrated surface movement, multimodal airport collaborative decision-making and flow optimisation, next-generation arrival manager in a 4D context, and enhanced integration between airspace users' trajectory definitions and ATM Network Manager processes. The target is to have two pilot implementations of fully integrated multimodal smart airports with the ATM network before 2027.
- **An integrated transport network performance cockpit.** The aviation network performance cockpit introduced previously will be further developed into an overall transport network performance cockpit to improve passenger experience and planning. This will require collaboration between different modes of transport, a detailed analysis of existing data and processes for their integration, and the specification of needs for additional data collection and analysis. Data from various sources, aligned with powerful analytics, will allow the creation of data-based services supporting journey optimisation and personalisation of offers to customers. EU general data protection rules will be respected to protect personal data. For aviation, the Network Manager's data collection and processes will be enhanced to support the multi-model dimension. Enhanced transport performance indicators will be developed to support the analysis of passenger experience based on the current SES performance scheme, ICAO, EU connectivity indicators and indicators used in other modes of transport. Prospective socioeconomic studies will provide insight into the challenges of the evolution of air transport within the general transport system. The target is to support the implementation of the ATM network performance cockpit by 2023 and, on this basis, to develop the detailed integrated transport network performance cockpit concept and requirements by 2027.
- **An integrated transport network crisis management process.** Recent events (e.g. terrorist attacks) have demonstrated the need to coordinate – when managing a crisis – between different modes of transport and a multitude of actors, including local and national authorities' representatives, to increase overall transport system resilience and provide a better service to customers. The target is to develop, starting from the Network Manager crisis management process, the detailed requirements and concept for the integrated transport system crisis management process, before 2027.

B.7 Aviation Green Deal

The objective of net-zero greenhouse gas emissions by 2050 set by the European Green Deal, in line with the EU's commitment to global climate action under the Paris Agreement, requires accelerating the shift to smarter and more sustainable mobility. This implies the need for aviation to intensify its efforts to reduce emissions. To this end, a set of operational measures to improve the fuel efficiency of flights will have to be put in place with the aim of enabling aircraft to fly their optimum fuel-efficient 4D trajectory. At the same time, to ensure sustainable air traffic growth, it is necessary to speed up the modernisation of the air infrastructure to offer more capability and capacity, making it more resilient to future traffic demand and adaptable through more flexible ATM procedures. Furthermore, reducing aircraft noise impacts and improving air quality will remain a priority around airports.

The following eight R & I needs have been identified in relation to this flagship.

- **Optimum green trajectories.** The objective is to enable aircraft to fly their optimum fuel-efficient 4D trajectory (cross-border, where applicable). ATC actions should preserve, as much as possible, this optimum green trajectory from any potential degradation and from the associated additional emissions. Thanks to data sharing between all the actors (e.g. airlines, airports at departure and arrival, Network Manager and often, multiple national air navigation and data service providers) involved in the execution of a given flight, monitoring tools and appropriate measures have to be defined to remove or reduce any gap between the optimal 4D trajectory and the planned or in-execution trajectory. In terminal areas, it will be necessary to find the best possible compromise between maintaining the optimum fuel-efficient 4D trajectory and minimising the noise impact. Optimal green trajectories should also include and anticipate the challenges and performance characteristics of new aircraft types and propulsion that the European Partnership for Clean Aviation will deliver.
- **New ways of flying.** This includes the exploration of innovative flight operations based either on existing or future avionics that reduce the environmental impact of aviation (both emissions and noise) without compromising safety, for example more efficient ATFCM services or the application of short-term ATFCM measures to flight paths, limiting the need to apply horizontal and vertical reroutings.
- **Formation flight.** Using the principle of wake-energy retrieval, like migrating birds, formation flight tests have demonstrated that significant fuel savings (between 5 % and 10 % per trip) could be achieved when two aircraft fly approximately 3 km apart, without compromising passenger comfort and safety. R & I activities will develop the required avionics and the necessary ATM procedures to develop demonstrators and prepare for market uptake.
- **Advanced required navigation performance green approaches.** A new procedures design will allow the definition of shorter horizontal paths of arrival while ensuring low noise impact over populated areas. For instance, by using the most advanced required navigation performance aircraft capabilities and by sharing precise 4D trajectories, further optimisation of arrival trajectories can be achieved with shorter downwind legs, shorter final legs and optimal transition from cruise phase. The integration of each improvement into an optimal arrival trajectory will shorten flight times and emissions while maintaining the noise impact at the most acceptable levels.
- **Environmentally optimised climb and descent operations.** While a major collaborative effort is needed for the deployment of optimised climb and descent operations' procedures in many European TMAs and airports, with most promising environmental benefits, further studies will explore the potential of additional optimisation (e.g. delaying the deceleration phase closer to the airport). The potential for improvement will depend on both the baseline standard speed management strategy of each TMA and the sequencing method used, and needs to be further assessed in terms of benefits and applicability to European TMAs.

- **Non-CO_2 impacts of aviation.** The impact on the climate of non-CO2 emissions (NOx, SOx, H2O, particulate matter, etc.), such as contrails and induced cloudiness, is potentially large. In particular, the trade-off between avoiding areas where aircraft-induced clouds form and reducing CO2 should be studied further.
- **Impact of new entrants.** The introduction of new types of air vehicles, such as hybrid-electric / hydrogen / electric aircraft, drones/UAVs or supersonic/hypersonic aircraft, will offer new opportunities for the development of the air transport of freight and passengers, adding to the flexibility of the system, reducing D2D journey times and, with the use of non-fossil fuels, reducing or eliminating associated emissions. At the same time, however, they could create new annoyances and fears among the population overflown (noise; visual pollution, particularly at night; intrusion into privacy; risks to third parties, etc.) and even risks to wildlife (e.g. migrating birds, nesting areas), notably in locations where no nuisance from aviation existed before. These impacts need to be studied further, and the operations of these new entrants adjusted to minimise them.
- **Accelerating decarbonisation through operational and business incentivisation.** Optimisation of flight operations (including taxiing at the airport) from an environmental perspective in the context of a full D2D green mobility.
- Emission-free taxiing traffic management: Using a turbofan engine for taxi movements results in extended use and wear of aircraft wheel brakes as well as high emissions of carbon monoxide, unburned hydrocarbons and particulate matter, impacting local air quality. The use of emission free taxiing, without comprising punctuality, could make a fuel saving of around 2%, and as such should be further studied and generalised.
- Environmental dashboard: The collaborative management of environmental impacts and the implementation of strategies to reduce them requires the development of indicators/metrics that will enable on one hand all ATM decision-makers to make informed decisions at strategic, pre-tactical or tactical level and on the other hand to communicate on ATM community efforts towards environmental sustainability.
- Environmental impact assessment toolset: There is a need to develop further the set of European environmental impact assessment tools, in order to analyse, inter alia, the integration of new entrants into the future ATM system and the overall environmental benefits and impacts they will have. Due to the complexity and diversity of environmental impacts, particular attention needs to be paid to the analysis of trade-offs, between environmental impacts, but also possibly with other performance areas.
- Environmental impact assessment methodology and new metrics: It is necessary to develop further the methodology used in SESAR 2020 not only to cover the research phase, but also the deployment and implementation phases. As part of this methodology, the use of big data analysis and machine-learning should be extended to the development of new environmental metrics that will be used to monitor environmental impacts and incentivise actors to promote compliance with environmental targets and regulations. These metrics will also be integrated into the Environmental Dashboard, and into the Environment Impact Assessments toolset.
- Climate resilience and adaptation: All future ATM solutions must demonstrate their resilience to projected future meteorological and atmospheric conditions, which could become increasingly extreme.

B.8 Artificial intelligence for aviation

ATM decision-support techniques, mostly based on heuristics, present limitations in terms of the technology itself. Hence the performance improvements of the future cannot be achieved using legacy software system approaches. AI is one of the main tools that will allow the current limitations in the ATM system to be overcome. A new field of opportunities arises from the general introduction of AI, enabling higher levels of automation and impacting the ATM system in different ways. AI can identify patterns in complex real-world data that human and conventional computer-assisted analyses struggle to identify, can identify events and can provide support in decision-making, and even optimisation. Over recent years, developments and applications of AI have shown that it is a key ally in overcoming these present-day limitations, as in other domains. Tomorrow's aviation infrastructure will be more data-intensive and, thanks to the application of machine learning, deep learning and big data analytics, aviation practitioners will be able to design an ATM system that is smarter and safer, by constantly analysing and learning from the ATM ecosystem.

The following four R & I needs have been identified in relation to this flagship.

- **Trustworthy AI-powered ATM environment.** New and emerging AI capabilities will be required for the future ATM/U-space environment in order to provide the necessary levels of performance beyond current limits. R & I is a key lever to deploy this technology and generate trustworthiness around AI in aviation, always considering a human-centric approach in line with the EASA AI roadmap[39].Beyond the work conducted by the EUROCAE AI working group, there is the need to focus on the development of new methodologies for the validation and certification of advanced automation that ensure transparency, legality, robustness and stability under all conditions and with full consideration of a future ATM environment built on multiple AI algorithms system of systems, with a human-centric approach.
- So far, AI has been largely dependent on data, as is necessary to develop AI algorithms and to validate them. Thus, the challenge is to develop an appropriate aviation/ATM AI infrastructure that can capture the current and future information required to support AI-enabled applications with the required software development processes, using robust architectures for ATC systems to provide ATCOs and pilots with a good level of confidence in automation and decision-aiding tools.
- In addition, to cope with higher levels of automation, there is a need to foster access to and sharing of data while looking at data quality, data integrity, ownership, security, trust framework and data governance aspects, which will mean building an inclusive AI aviation/ATM partnership, aiming for a potential leadership for AI in aviation in Europe by defining, learning and implementing together.
- **AI for prescriptive aviation.** AI will help aviation to move forward from a reactive (to act when a problem appears) to a predictive (anticipating a problem, enabling innovative preventive actions) and even a prescriptive paradigm (adding the capability to identify a set of measures to avoid the problem). AI applications will impact all flight phases from long-term planning through operational to post-operational analysis.
- New disruptive events (e.g. the COVID-19 pandemic) have recently shown that aviation requires the implementation and adaptation of new solutions to face unexpected events of which we have no prior experience. The resilience of the ATM system in this regard should be addressed.
- AI/ML have great potential for predictions/forecasts under normal circumstances, but need further evolution if they are to be used in the management of abnormal situations: a prescription-oriented approach will be needed to monitor reality and define precursors to detect deviations from what is expected. More time for reaction is the expected result. For major non-nominal situations (such as volcanic ash clouds or COVID-19), new methodologies will be researched to cope with the AI gap. This includes not just the tactical phase but also the strategic phase, when the operators of the system may be interested in exploring what should be done to achieve a certain multi-objective system performance (e.g. by balancing capacity, cost-efficiency and environmental impact), and a prescriptive system would be able to identify strategies.

[39] https://www.easa.europa.eu/newsroom-and-events/news/easa-artificial-intelligence-roadmap-10-published

- **Human–AI collaboration: digital assistants.** The interaction between humans and machines powered by AI, or other sub-branches such as reinforcement learning, explainable AI or natural language processing, will positively impact the way humans and AI interact. These advances aim to increase human capabilities during complex scenarios or to reduce human workload, not to define the role of the human or to replace the human, but to support the human.
- Aviation will need to ensure a human-centric approach as described in the EASA AI roadmap. Humans should understand what the systems are doing and also maintain the right level of situational awareness, that is to be cognisant of the situation to enable human–machine cooperation. The different levels of ATM automation (0–5) described in the European ATM Master Plan and the Airspace Architecture Study, and also linked to Master Plan phases, present an evolution in the way that the human and the system interact, with different transparency and explainability needs. This SRIA aims to lay the foundations for an automation level of up to 4.
- AI-based human operator support tools that ensure the safe integration of 'new entrant' aircraft types into an increasingly busy, heterogeneous and complex traffic mix (i.e. UAVs, supersonic aircraft, hybrid and fully electric aircraft) should be developed. In addition, AI-powered systems are expected to be integrated into ground/cockpit systems, enhancing communication for trajectory management and much more. Digital assistants will request to be connected to the avionics world in order to ease data exchanges: in this context, cybersecurity will be a key enabler of these exchanges. Moreover, digital assistants will support pilots, thus reducing the workload (e.g. automating non-critical tasks, adapting the human–machine interface during operations). This is a first step towards introducing the artificial co-pilot necessary for future operations such as SPO.
- There will be a need to develop new human–machine interfaces for ATCOs (e.g. augmented reality) and the capability to monitor ATCO workload in real time based on AI, as well as new skills and new training methods to support these new joint human–machine systems.
- **AI-improved data sets for better airborne operations.** Data sets are essential to AI-based application development. R & I should be conducted to generate, and in particular to enable the automation of, aviation-specific data sets from a large variety of on-board and ground communications across the network, which could then a enable broad range of AI-based applications for aviation (e.g. voice communications between ATC and pilots). New sensors will be loaded on board (drones/UAV and aircraft) such as camera, millimetre-wave radar, DAA, light detection and ranging (lidar) in order to be able to execute new types of operations (automatic take-off or landing, etc.). These new operations will require new functions, such as intelligent augmentation tools, vision-based navigation or trajectory optimisation. This will enable the use of AI as a response to the European Green Deal, applying operational strategy based on environmental criteria and developing AI-based solutions to operational mitigations of aviation's environmental impact, such as near-real-time network optimisation (airspace/route availability) and use (on-the-fly flight planning), in conjunction with meteorological data nowcasting, which could be made possible with AI.
- Furthermore, thanks to permanent high-bandwidth connectivity, most data and metadata could be processed either on the ground or directly on board. These functions will require a new high-performance service platform interfacing with the ground (or cloud) open world platform (AOC) and on-board avionics for which AI will be required to remain cyber-resilient. Aspects related to cybersecurity will need to evolve to cope with AI evolution needs.

B.9 Civil/military interoperability and coordination

The digital transformation of the European ATM network will have an impact on both civil and military aviation and ATM operations. Care must be taken to ensure a sufficient level of civil/military interoperability and coordination, especially concerning trajectory and airspace information exchange, as well as the use of interoperable CNS technologies. Therefore, a joint and cooperative civil–military approach to ATM modernisation would be the best choice to achieve the appropriate level of interoperability, and also to maximise synergies between civil and military R & D activities.

To achieve the SES objectives while at the same time enhancing military mission effectiveness, a joint R & D programme should focus on the following key priorities.

- **Access to airspace.** For reasons of national and international security and defence, military manned and unmanned assets will require access to airspace where and when needed. The size and location of airspace for military purposes will depend on respective mission profiles. In order to make optimal use of airspace for civil and military aviation, future system options for civil–military collaborative decision-making processes supported by common procedures, data formats and the underlying information exchange services should be examined. These future systems and procedures should be flexible enough to adapt to different operational scenarios and needs, and ensure optimal separation management (e.g. DMA 3), taking into account different and coexistent CNS air and ground capabilities. It is a precondition to accommodate civil and military operations in the same airspace.
- **Military surveillance capabilities.** To ensure situational security awareness and to improve the maintenance of their recognised air picture, military authorities must monitor the air traffic inside their national airspace. The increased availability of data (such as aeronautical, meteorological, environmental and flight data) in a digital format can improve military surveillance capabilities. As also identified in action area 4.9 of the ACARE SRIA 2017 update volume 1[40], military authorities must have full access to all available information without additional cost. Increased civil–military data-sharing requires solutions ensuring the appropriate levels of quality of service and security for military systems.
- **Connectivity and access to CNS infrastructure.** Future technical solutions making use of emerging Satcom and terrestrial data-link technologies and multilink, as well as advanced navigation and surveillance, should enable a joint civil and military utilisation, reducing technical constraints and costs while maintaining appropriate levels of safety, security and environmental sustainability. The connectivity and access to CNS infrastructure also requires solutions ensuring security and appropriate levels of quality of service. At same time, the integration of CNS and spectrum consistency in terms of robustness, spectrum use and interoperability is essential to define the future integrated CNS architecture and spectrum strategy. A service-driven approach, accommodating civil and military alike, is needed to describe how the CNS services are delivered for navigation, communication, surveillance and traffic or flight information, including cross-domain services (e.g. contingencies). Further military and civil interoperability is expected in terms of the common use of CNS, rationalising civil infrastructure and costs, taking into account the capacity of military legacy systems to evolve. Research initiatives are needed to enable the use of multimode avionics relying on software-defined radios and reliance on enhanced visual systems and airborne surveillance to mitigate airborne collision functions. The success of military missions depends on adequate access to radio frequency spectrum resources, in particular to ensure the mobility and interoperability of forces. The digitalisation of ATC systems enables virtualisation approaches whereby remote operations become an important contributor to resource pooling, sharing and rationalisation. Virtual control centres allow for a more efficient and flexible use of resources, with civil/military synergies.

[40] "Strategic Research & Innovation Agenda" 2017 Update, Volume 1, Advisory Council for Aviation Research and Innovation in Europe (ACARE).

- **Cybersecurity.** In a highly information-oriented operational system, data become a core asset to be protected. Civil–military data-sharing requires solutions ensuring the appropriate levels of quality of service and security for military systems. A necessary precondition to support the digitalisation of processes is a sufficient level of cybersecurity and data protection, which should be considered holistically in an end-to-end information management process. Further aspects to consider are personnel education, training and capacity-building, technical infrastructure and increased cooperation and information-sharing among civil and military authorities.
- **Performance orientation.** Environmental sustainability, cost-efficiency or delays imposed by inefficient use of available capacity represent a concern for which all aviation stakeholders have to assume responsibility. The complex interdependencies between civil and military stakeholders need to be examined to enable appropriate performance measurements in a spirit of balanced consideration between commercial needs and security and defence requirements.

C. Airspace Architecture Study

The following sections are extracts of the key elements of the Airspace Architecture Study that can be found in the SESAR 3 JU website at https://www.sesarju.eu/node/3253.

C.1 Combining airspace design and technological solutions

Delivering the vision outlined in the European ATM Master Plan will require changes in the way that technologies are developed and deployed, as well as in the way services are provided. This change in approach builds on the recommendations made in 'A proposal for the future architecture of the European airspace', developed by the SESAR Joint Undertaking with the support of the Network Manager and delivered to the European Commission in February 2019.

Known as the Airspace Architecture Study, the proposal seeks to address the airspace capacity challenge in the medium to long term by combining airspace configuration and design with technologies to decouple service provision from local infrastructure and progressively increase the levels of collaboration and automation support.

The findings and recommendations of the study, including its follow-up work, have been fully taken into consideration when developing the SESAR 3 JU Multiannual Work Programme.

C.2 Accelerating market uptake through demonstrators

The SESAR 3 JU Multiannual Work Programme takes into account, in particular, the proposed gradual implementation of an EU network of large-scale 'Digital Sky Demonstrators' (Airspace Architecture Study transition plan measure 3). This network, tightly connected to standardisation and regulatory activities to fix the industrialisation gap, will be an acceleration platform for a critical mass of 'early movers' representing (pending availability of budget) a minimum of 20 % of the targeted operating environments, as defined in the European ATM Master Plan, in order to complete pre-implementation activities and maximise the chances of later market uptake throughout the network, as foreseen in the Airspace Architecture Study. Demonstrators will include testing, in a live environment, concepts, services and technology supporting the achievements of the Airspace Architecture Study. This will help build confidence from the supervisory authorities and operational staff by building further performance and safety evidence.

D. Supporting safe and secure drone operations in Europe (consolidated report on SESAR U-space research and innovation results)

The following sections are extracts of the key elements of the "Consolidated report on SESAR U-space research and innovation results" that can be found in the SESAR 3 JU website at https://www.sesarju.eu/node/3691.

D.1 Introduction

In 2017 and 2018, the SESAR JU launched 19 exploratory research projects and demonstration projects aimed at researching the range of services and technological capabilities needed to make U-space a reality. The projects brought together some 25 European airports, 25 ANSPs, 11 universities, more than 65 start-ups and businesses and 800 experts, working in close cooperation with standardisation and regulatory bodies, including EUROCAE and EASA. This document presents the consolidated findings of those projects41.

The central outcome of the research is the U-space ConOps, providing an initial U-space architecture and description of airspace types and U-space services to enable safe and efficient VLL drone operations.

In parallel, the projects researched, developed and demonstrated U-space services from U1 to U3 in a variety of geographical environments and airspace classes, while taking into account several types of flight mode and operational environment. The projects also looked at the density of drone traffic, as well as the complexity of the traffic and service provision, including multiple simultaneous service providers.

An analysis of the activities shows that, collectively, the projects addressed all U1 services and almost all U2 services. Meanwhile, only limited coverage was achieved for U3. U4 was not covered by the research activities.

In terms of the level of readiness, the projects demonstrated that U1 and U2 services were ready for use in environments with low levels of complexity (rural areas, segregated airspace) and a low density of traffic.

In these environments, the projects were able to show the feasibility of multiple service provision, strategic deconfliction and the possibility of increasing situational awareness through information-sharing. They also demonstrated the importance of reliable tracking and monitoring and addressed the interface with manned aviation.

[41] See Consolidated report on SESAR U-space research and innovation results, SESAR JU, 2019 https://www.sesarju.eu/node/3691

Many technologies were successfully tested and demonstrated, but there is a strong need for performance requirements and system standardisation.

At the same time, the analysis underlined the need to further develop and validate U-space to cater for high-complexity / high-density operating environments (urban operations, mixed traffic). This will require further R & I, in particular in relation to conflict management, emergency management and monitoring services – it is these services that will make U-space scalable and robust to support dense and complex operations in U2 and to ensure a transition to U3 and U4.

D.2 Findings

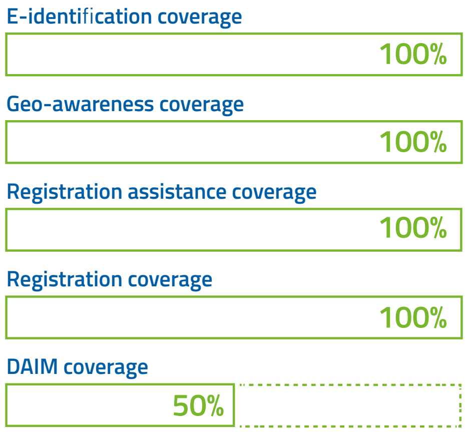
D.2.1. Is U-space fully covered?

The U-space services were researched, developed and demonstrated in a variety of environments (urban, rural, suburban) and airspace (controlled, uncontrolled), taking into account numerous types of flights (manual, partly automated, fully automated, mixed) and operations (visual line of sight (VLOS), beyond visual line of sight (BVLOS), VLL, above VLL), the density of drones, the complexity of the traffic (e.g. simultaneous flights) and the complexity of the service provision (e.g. multiple service providers). This led to a high number of possible service combinations, the analysis of which provides a picture of the coverage of the services researched by the projects.

D.2.2 Foundation services (U1)

An analysis of the individual reports shows that U1 services were fully addressed by the projects. For example, the registration assistance service was demonstrated by the 'D-flight internet of drones environment' (DIODE) project, with use cases involving one single USSP, which corresponds to a low-complexity environment (see Figure 21).

FIGURE 21: **U1 COVERAGE**



D.2.3 Initial services (U2)

Due to activities taking place in parallel, the demonstration projects based their work on the CONOPS (first edition – June 2018), while the current analysis considers the latest CONOPS (third edition – September 2019) as the reference. It is therefore not surprising to see that U2 services introduced in this latest edition (e.g. citizen reporting) are only partially covered by the projects. This is also the case for other services first introduced in the third edition, such as the population density map or electromagnetic interference information services. The overall U2 coverage is shown in Figure 22.

However, some projects address services that were not featured in the first CONOPS, such as geospatial information service. The Finnish–Estonian 'Gulf of Finland' (GOF) very large U-space demonstration project (GOF U-space) and the 'European UTM test bed for U-space' (EuroDRONE) project demonstrated this service by addressing some cases involving only one unique USSP. The scenarios were based on partially automated flights in controlled airspace and fully automated flights in uncontrolled VLL airspace.

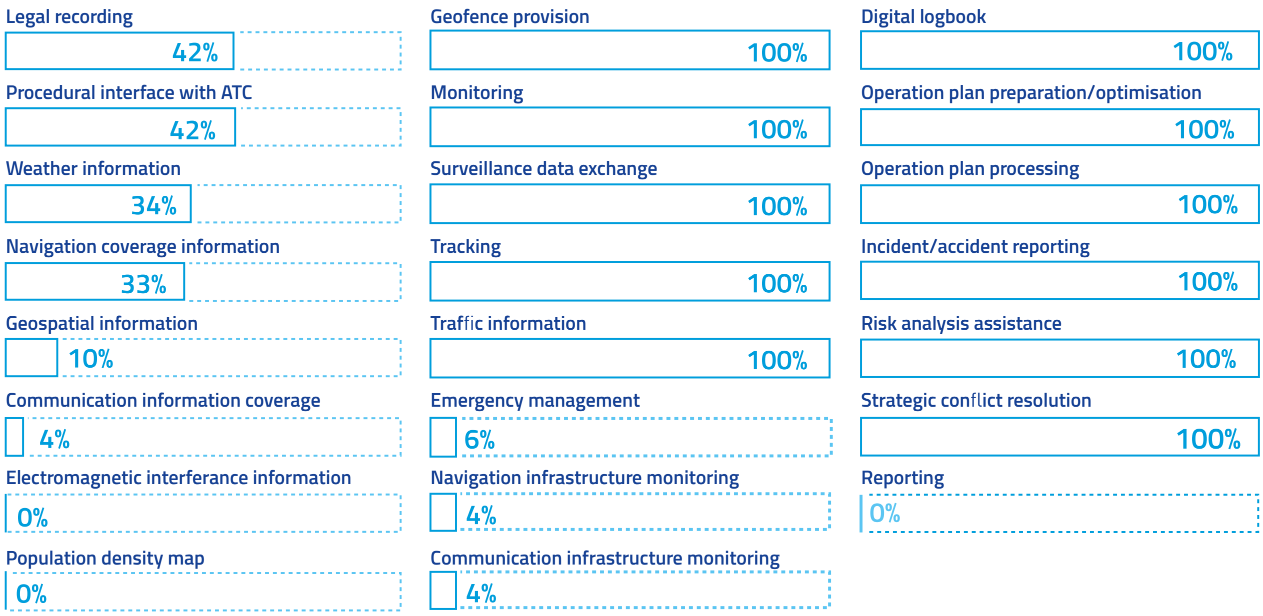
U2 is the main block of services for U-space when considering the services initially defined at the start of the research activities by the SESAR JU. As shown in Figure 22, almost all these services are fully covered.

Some services were partially covered, as is the case for emergency management, which the DIODE, 'Demonstration of multiple U-space suppliers' (DOMUS) and EuroDRONE projects looked at. Their investigations were limited to uncontrolled airspace, in VLLs, and with only one USSP at a time.

Research was also done on the communication and infrastructure service by EuroDRONE. Its investigations covered scenarios involving fully automated flights in uncontrolled airspace and one USSP.

Meanwhile, DOMUS and EuroDRONE addressed the navigation infrastructure service with scenarios covering only uncontrolled airspace, which means that controlled airspace requires complementary activities.

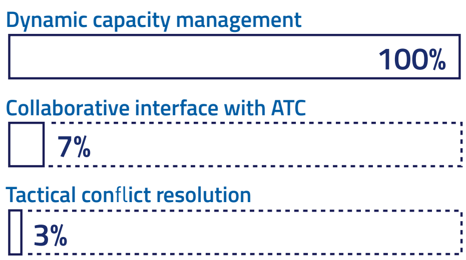
FIGURE 22: U2 COVERAGE



D.2.4 Advanced services (U3)

The coverage of U3 services is mixed, as indicated in Figure 23. While the dynamic capacity management service was covered by various demonstration projects, only a limited number of configurations were carried out addressing the tactical conflict resolution service – notably by the 'Validation of U-space by tests in urban and rural areas'(VUTURA) project and the 'Safe and flexible integration of initial U-space services in a real environment'(SAFIR) project, which delivered a first set of valuable conclusions on tactical conflict resolution. Similarly, only a limited number of activities were carried out on the collaborative interface with ATC. Several projects, such as VUTURA and SAFEDRONE, developed solutions for this service, with demonstrations involving one single USSP and unmanned vehicles only.

FIGURE 23: **U3 COVERAGE**



D.2.5 How mature is U-space?

In order to assess the maturity of U-space technologies, the SESAR JU research programme worked from two basic assumptions: the first assumed that U1 services are ready and available now; the second assumed that U2 services are technically possible and can be realised today. SESAR JU projects were then designed to test these assumptions and report on the extent to which they were true.

While the projects provide plenty of examples where U1 (foundation) services, such as geofencing and identification, are already available, they also clearly showed that a lack of standardisation has led to variations in performance. In addition, there are gaps in capability, for example in sharing information with other stakeholders or operating multiple drones. Similarly, while advanced technology supports many U2 (initial) services, including tracking and monitoring, flight planning and communications, delivery of these services was characterised by underperformance in connectivity and interoperability.

Results coming from this first round of SESAR exploratory research and demonstration activities allow, for the first time in Europe, conclusions to be drawn from a series of projects that address the full range of issues that need to be covered to implement U-space. This allows for a rigorous analysis of both where we stand and how to focus further work to enable U-space to reach a higher level of maturity. For example, many business models need drones to safely carry out long-distance operations known as BVLOS. These include reliable two-way communications during flight and the means to identify and track drones while in the air so that the flight can be safely managed and deconflicted from manned aircraft and from other drones.

In conclusion, the projects demonstrated that U1 and U2 services are ready for environments with a low level of complexity (rural areas, segregated airspace) and a low density of traffic. At the same time, conclusions show the need to further develop and validate U-space to fit with the high-complexity / high-density (urban operations, mixed traffic) of future operating environments.

As further explained, all the U2, U3 and U4 services are subject to future R & I activities. Some of them are more critical: conflict management, emergency management and monitoring services are those that will make U-space scalable and robust to support dense and complex operations in U2 and will ensure a transition to U3 and U4.

D.2.6 Key milestones

The following are some of the key highlights and findings drawn from the projects to illustrate service coverage and maturity.

D.2.6.1 Delivering a concept of operations for U-space

The CORUS project received broad consensus for the U-space CONOPS. It provides an initial U-space architecture and detailed definition of the airspace types to be used for VLL drone operations and the services within them so that operations are safe and efficient. It describes U-space from a user's perspective, showing how it will be organised and detailing the rule-making that is under development. The CORUS CONOPS shows, for the first time, a complete picture of U-space that can be easily understood and that can form a foundation on which U-space implementation throughout Europe can be based.

D.2.6.2 Showing the feasibility of multiple service provision

A key aim of the development of U-space in Europe is the promotion of an open drone market, enabling operators and service providers alike to build this new ecosystem without having to adopt the structure of more traditional ATM. This will support the operation of multiple simultaneous service providers operating both in cooperation and in competition. The SESAR JU projects provided an opportunity to progress from demonstration flights to introducing drone services in the future. The port of Antwerp, for example, explored inspection technology that was demonstrated during the SAFIR project, extending over 120 km^2. The port authorities found the drones 'an immense addition to safety' as they were able to 'manage, inspect and control a large area in a swift and safe manner.' SAFIR succeeded in interconnecting multiple unmanned aircraft systems traffic management (UTM) systems and supported a variety of drone types. It established Antwerp as one of the key locations in Europe where U-space is advancing in a real operating environment. It also recommended further research into interaction with ATC and performance requirements for satellite mobile connectivity. The project showed how technology can support multiple service providers, a core requirement for complex future applications.

D.2.6.3 Supporting strategic deconfliction

Among key capabilities, foundational U-space services (U1) such as e-registration, e-identification and geofencing were successfully demonstrated by the DIODE project. Flights conducted in real-life environments, including precision agriculture, parcel delivery, road traffic patrolling, surveys and search and rescue, showed that capabilities on board drones can manage containment. The project also showed how a USSP can provide a safe operational environment by exchanging information with drones and ATM. This supports strategic deconfliction for a limited number of operational drones, allowing initial trials in Italy in 2019. Advanced conflict detection is essential for multiple drones to operate simultaneously, and this was tested by the DOMUS project. DOMUS used a federated architecture to show how several USSPs can support drone operations using key functionalities, including dynamic geofencing and tactical deconfliction, to deliver dynamic flight management in real time. The project integrated already developed technologies to support optimum operation profiles and fleet management while ensuring safety, security and privacy. A principle service provider, called the Ecosystem Manager, provided a single point of truth and an interface with ATC. DOMUS investigated the full range of U1 and U2 services, and demonstrated solutions, for example enabling a controller to create a geofenced area around a manned aircraft, in addition to interoperability between different U-space services.

D.2.6.4 Increasing situational awareness through information exchange

A basic function of U-space is to bring situational awareness to all actors, and information exchange is fundamental to achieving this. Safe drone integration in the GOF U-space trial established an interoperability architecture to integrate existing solutions and used this to support operations ranging from parcel delivery, inspection services, police operations and search and rescue in maritime and city environments. The architecture relies on standard protocols to exchange data and serves as a flight information management system, which disseminates information about manned and unmanned vehicles to a wide range of stakeholders, including local and national authorities, ANSPs and USSPs. By using an open platform and SWIM, the solution collectively and cooperatively manages all drone traffic in the same geographical region. In the real-life demonstrations, the platform enabled manned and unmanned aircraft to safely share the same airspace by providing operators and pilots with access to common flight information.

D.2.6.5 Focusing on tracking and monitoring

GOF U-space was one of several projects that also showed the importance of reliable tracking data for all airspace users. Flight tests assessed the performance of multiple collision avoidance and tracking systems (e.g. automatic dependent surveillance – broadcast (ADS-B), FLARM) and, while these technologies could all support surveillance, experience revealed inconsistencies in performance. Project results thus highlighted the need for interoperability and for further work on standardising such technologies. Similarly, the reliability of data communications is key to the timely delivery of information, so U-space services need to be resilient to loss of mobile network coverage. Another project that tested secure tracking and identification of drones was U-space initial services (USIS). During long-distance flights in France and Hungary, SESAR JU partners relied on advanced flight planning, authorisation and tracking services, and successfully used cloud-based platforms to manage multiple numbers of unmanned operations. USIS validated the integration between the UTM platform and the e-identification and tracking of drones; it also showed how flexible flight planning supports multiple drone operations and recommended more research involving more participants. Meanwhile, partners in the Technological European research for RPAS in ATM (TERRA) project assessed whether machine learning can help monitor VLL operations, including early detection of off-nominal conditions such as trajectory deviations. They found that artificial neural network modelling could be used for predicting and classifying drone trajectories in urban scenarios.

D.2.6.6 Addressing the interface with manned aviation

Interaction with manned aviation proved to be one of the most challenging areas of research. For unmanned and manned vehicles to share the same airspace, flights need to be visible to other airspace users. This is especially important in the lower airspace, where general aviation accounts for over 100 000 users in Europe. Maintaining the safety of air operations when drones and conventional aircraft share low-level airspace, close to an airport for example, will require a high degree of digitalisation and automation. This was one of the key areas addressed by partners in the SAFEDRONE project. Over the course of 2 years, the project partners looked at the increased levels of autonomy necessary to operate in non-segregated airspace and to carry out dynamic in-flight activities such as on-board replanning trajectories within the U-space approved flight plan, and autonomous generation of coordinated trajectories within an approved U-space area of operation. It assessed the viability of using 4G networks for communication during BVLOS flights and GNSS technologies for drones to report an accurate altitude so that the UTM system can use it.

The interface with manned aviation was also addressed by the GOF U-space project, whose demonstrations marked the first time that general aviation aircraft, drones and recreational remote-controlled model aircraft shared controlled airspace above and around an operational airfield. The project showcased the core vision of U-space, increasing transparency for all users, including drones, general aviation and other airspace users, who are able to access digital tools that the current UTM solutions provide in order to create situational awareness for everyone. Mobile 4G networks were used to relay situational awareness data to both ground crew and general aviation flying up to 2 000 ft, tracking targets using transponders, FLARM and mobile network-based position trackers.

An important finding from all the projects that looked at the interactions with manned aviation was the need for a common altitude reference. Different drones used different mechanisms for measuring and a harmonised approach that could support the management of a vertical profile with regard to other drones or manned aircraft. This is one of the key findings from the technologies tested that have been passed to EASA and the standardisation bodies, EUROCAE and the Global UTM Association, to help develop standards that will enable the safe integration of drones in the airspace.

D.2.7 Harnessing results from non-U-space SESAR research projects

Thanks to its broader mandate, the SESAR JU has a comprehensive and integrated view of ATM and the operational needs of all airspace users. This means that insights drawn from one area of its R & I activities can be fed into other areas of the programme, when relevant. This is the case of a number of research projects from SESAR JU's core innovation portfolio, the results of which are providing valuable additional findings about cost-efficient solutions that may be of interest to the drone community. In the area of surveillance, for example, a project on improving navigation and surveillance in general aviation used low-cost, low-power ADS-B transceivers to show that electronic conspicuity helps general aviation pilots integrate with other airspace users without incurring high costs or requiring additional certification. The results showed that general aviation pilots were able to avoid potentially hazardous situations as a result of improved traffic situational awareness before visual acquisition. Reliable communications are essential to support safe operations, prevent mid-air collisions and enable dynamic flight planning.

The EMPowering Heterogeneous Aviation through cellular SIgnalS (EMPHASIS) project examined affordable cooperative surveillance that is available using a low-power ADS-B transceiver – which could be carried on board each drone and are becoming readily available. However, further work is required to ensure that such developments do not impact the critical 1090 MHz spectrum. The research also found that general aviation could interact successfully with unmanned vehicles using 4G/5G data links and justifies further R & D.

D.3 Future research and development needs

D.3.1 Urban air mobility

UAM refers to an ecosystem that enables on-demand, highly automated, passenger- or cargo-carrying air transport services with particular reference to the urban, suburban and interurban environments, where aviation is often highly regulated today. The UAM industry vision involves new vehicle designs (e.g. low-emission / low-noise eVTOL aircraft), new system technologies, the development of new airspace management constructs, new operational procedures and shared services to enable an innovative type of transport network.

A growing number of manufacturers are working on UAM solutions and eVTOL technologies to enable runway-independent operations, with very high degrees of automation, up to and including fully self-piloted aircraft. Most operators envisage a significant number of simultaneous operations around metropolitan areas at altitudes of up to 5 000 ft and speeds of up to 150 knots. These aircraft will typically carry cargo or one to four passengers on short trips (e.g. less than 100 km).

UAM is one of the most demanding use cases for U-space services: it requires exploring dependencies between services and approaching U-space as a system of services from the operational and performance perspectives. Future R & D has to explore these dependencies between services to make U-space robust and scalable and to maintain the safety level.

Looking at UAM, a review of the European Drones Outlook Study should be made to update the predicted drone traffic and expected business activity regarding UAM. A study of the social acceptance of the expected traffic would be beneficial to support the future development and implementation of UAM. The take-off and landing solution for UAM (often called a vertiport) will have to be defined and developed to address all weather conditions for which operations will be authorised, as well as all contingencies.

In addition to flying taxis, UAM covers all types of urban air operations that will require the extension of U-space services beyond the VLL limit. Drone operators and UAM operations will require access to higher altitudes and areas close to commercial manned aviation (e.g. airports); at the same time, flying manned aircraft in or adjacent to VLL could make use of U-space services. A safe and equitable integration of these operations with manned aviation will require additional U3 and U4 services.

The development of interoperability and a collaborative decision-making process between the urban operations, ATM and city authorities is key for future urban operations. It will therefore be necessary to consider the roles and responsibilities of the national and local stakeholders (including U-space service providers or USPs, UAS/UAM operators and ATM units involved). It will also be imperative to study the workflows they collectively engage in: defining solutions for ensuring the effective interoperability of USSPs and a proper interface with ATM; focusing on urban/suburban/airport scenarios and classes of airspace; and addressing governance and regulatory challenges, security and non-aviation aspects for easing social acceptance.

Further guidance is required on how urban ground and air risks should be addressed or airspace designed over these densely populated environments. It is still unclear how these proposed data and information services, managed by ATM and USSPs, can be integrated and implemented in the busy urban U-space to adequately manage the relevant risks, properly design the relevant airspace and efficiently and safely manage high volumes of UAS/UAM traffic.

Some initial information services for these three aspects have already been defined, but it is less clear how these inputs will be integrated and structured into a practical urban/suburban U-space system to manage potentially hundreds, if not thousands, of UAS/UAM movements per hour.

The primary safety hazards posed by UAS/UAM traffic operating in an urban/suburban/interurban environment are collisions between a drone and another airspace user, as well as the impact on infrastructure, objects and people on the ground, causing damages, injuries or possibly fatalities. The risks associated with these safety hazards must be addressed through the appropriate certification of drones for operation over an urban environment, coupled with comprehensive airspace architecture and dependable traffic management. Conventional drone risk-analysis modelling methodologies, such as specific operational risk assessments (SORAs), are useful for assessing risk for a single drone or a small number of drones operating in relatively uncomplicated real-world environments (e.g. sparsely populated, rural areas). However, this methodology may not be best suited in scenarios where high volumes of drone traffic are projected to operate in the near future over densely populated environments.

Key needs in developing urban U-space systems are:

- identifying and categorising the unique characteristics of VLL and low-level urban environments;
- drafting more pragmatic approaches to identify and properly address relevant risks;
- developing guidance regarding the design and development of integrated urban airspace architecture;
- completing the definition of the UAM operations framework to build a consistent approach on how urban U-space systems should be operated.

D.3.2 Air traffic management / U-space convergence

The introduction of new types of aerial vehicles within the airspace requires ensuring a fully collaborative approach between all actors with the objective of ensuring an efficient interface between U-space and ATM, as well as avoiding airspace fragmentation. An efficient U-space–ATM interface is required to enable an adequate, robust and timely exchange of U-space information services between various U-space stakeholders, such as drone and UAM operators, USP, ATM service providers, data service providers, aeronautical data providers and authorities. The relevant solutions are expected to have a positive impact on access and equity, enabling seamless ATM/U-space high-density automated and fully digitalised operations managed in close cooperation with UAS/UAM fleet operators.

A fully integrated ATM/U-space CONOPS definition is required to cover seamless operations inside and outside controlled airspace, further defining the interface between ATM and U-space, as well as examining the corresponding information exchange concept and requirements. Information exchange will be critical to enable a safe convergence of U-space and ATM. The possibility of a fully integrated airspace without segregation between U-space and ATM users is the ultimate goal.

A fully integrated ATM/U-space ecosystem without segregation between U-space and ATM operations also requires the setting up of common fundamental enablers. Some of these enablers include the definition of a common altitude reference system, separation minima, safe operating distances from buildings and fundamental aviation tenets, such as airspace classification.

The need to revise the rules of the air will be necessary to take into account the specificities of VLOS and BVLOS operations, of unmanned traffic in general and of mixed traffic (unmanned and manned). Such work will go through a mapping from VLOS and BVLOS to flight rules. If that mapping produces new flight rules, then the airspace classes need to be updated. X, Y and Z volumes need to be mapped to airspace classes, or guidance developed on what mappings are reasonable.

Further work will be required on enablers for automation and autonomy for U-space and UAS/UAM. In this framework, a critical aspect of the integration will be the role of humans, particularly regarding the high level of automation that will be delivered by U-space services and the known automation disparity between ATM and U-space. UAM integration into the ATM/U-space ecosystems is also a specific research topic, as well as the challenge of how to support the transition from piloted vehicles to UAM/autonomous operations. Of course, the evolution of the ATM/U-space convergence will need to be synchronised and coordinated with the development of UAM services and the certification of UAM vehicles. Special consideration should be given to the operational limitations of these new vehicles and how U-space and ATM can contribute to their operational safety by protecting their operations in contingency and non-nominal situations.

D.3.3 Advanced U-space services

The SESAR JU projects defined and demonstrated U1 and U2 services, as well as some early U3 services. It is now time to start work on the definition, design and development of the most advanced U-space services (U3/U4), which will also enable UAM missions in high-density and high-complexity areas. The required technologies to enable performance-based CNS services in U-space need to be identified and assessed in operational environments. These advanced steps in the deployment of U-space require advanced strategic/tactical conflict resolution, advanced DAA systems and a suitable communication infrastructure. This also goes together with the multiple USSPs principle: multiple USSPs working at the same time in the same geographical area.

D.3.3.1 Strategic/tactical conflict resolution

U-space services and capabilities will support a range of UAS/UAM operations ranging from rural sparsely populated areas with marginal manned aviation operations to urban operations with considerable manned aviation operations, terrain and surface obstacles to be considered. The corresponding requirements for separation provision / conflict resolution – in terms of data exchange/tracking/monitoring services, on-board aircraft capabilities/avionics and operators' responsibilities – will be adequate for the relevant risks to people and properties.

UAS and UAM operators operating in areas with high-density or heterogeneous/mixed types of traffic may be required to be equipped with DAA technologies to meet these requirements. Low-level manned aircraft operations in both uncontrolled and controlled airspace should have access to, and are encouraged to utilise, U-space mission management services to deconflict their operations from potentially conflicting unmanned operations in the same portion of airspace. Low-level manned aviation pilots will then share some responsibility with UAS/UAM operators for maintaining separation from each other (even if they will not share responsibility for separation from VLOS UAS operators).

U-space, within its defined airspace, should be ultimately responsible for maintaining an adequate separation among UAS/UAM, manned aircraft, airspace, weather events, terrain and other relevant hazards, and for avoiding unsafe conditions throughout the relevant operations. Separation/conflict management service provision will be achieved via shared intent, shared awareness, strategic deconfliction of airspace volumes, tracking and monitoring, some digital technologies supporting tactical deconfliction and the establishment of ad hoc operational rules and procedures. U-space services will support operations planning, intent-sharing, strategic and tactical conflict resolution/ management, conformance monitoring, operations authorisation, airspace management functions and management of off-nominal situations.

Until Europe has validated more advanced services and relevant technologies, U-space services supporting strategic and tactical conflict management cannot be fully deployed, yet these services are key for the adequate functioning of initial U-space implementations.

With its first portfolio of research projects, the SESAR JU has demonstrated several initial solutions for strategic conflict resolution (e.g. on delay in SAFIR and EuroDRONE, rerouting without considering terrain or other issues in DOMUS); however, these were limited in their ability to deconflict given the level of uncertainty: during the flight trials, no vertical separation was used.

Advanced conflict detection is essential for multiple drones to operate simultaneously. U-space systems must be implemented in a common way to be able to efficiently exchange data, and all systems have to be able to use the exchanged data. Low-quality / delay of input data from the other services degrade the strategic conflict resolution. These conclusions are about strategic conflict resolutions, but many parallels can be drawn with the tactical conflict resolution service.

Several areas will require further investigation in order to develop robust, advanced and scalable U-space services supporting strategic and tactical conflict management. These include:

- conflict management principles and related algorithms;
- the impact of the fairness principle on the decision-making process;
- how conflict detection should be optimised;
- how a common altitude reference system and vertical separation should be implemented;
- how conflicts should be resolved in a federated system;
- how conflicts should be resolved with manned aviation in VLL and low-level environments;
- strategic deconfliction introducing more variables: weather, GNSS availability;
- interactions between the tactical conflict resolution service and on-board DAA systems;
- use of machine learning in tactical conflict detection.

Finally, monitoring is a key enabler for strategic and tactical deconfliction (such as response and recover elements). Any research related to conflict management must therefore consider dependencies with monitoring services.

D.3.3.2 Detect-and-avoid solutions (cooperative and non-cooperative)

U-space will impose requirements on UAS / UAM / manned aviation operations and performance commensurate with the required level of services, operational environment and airspace class conditions. Airspace management will refer to a layered approach to safety, security and equity of airspace access that also includes the capability of ensuring aircraft and obstacle avoidance through the use of appropriate ground-based or on-board equipment, including DAA / collision avoidance logic. Based on that, it is expected that, in U-space airspace, UAS and UAM operators flying in areas with high-density or heterogeneous/mixed types of traffic may be required to be equipped with DAA technologies to meet these requirements. It means that, in terms of R & D needs, Europe should address the following needs:

- development of on-board DAA capability;
- full demonstration of DAA (detecting equipment for cooperative intruders) in dense airspace;
- exploration of technical feasibility for detecting non-cooperative intruders and integration with the current collision avoidance algorithms;
- cost-effective, lightweight electronic conspicuity and collaborative DAA developed by the PercEvite project needs to be further developed and matured for large-scale deployment in environments with and environments without U-space tactical conflict resolution;
- cost-effective, non-collaborative DAA developed by the PercEvite project needs to be brought to maturity;
- operational procedures are needed for pilots reacting to electronic conspicuity and DAA.

D.3.3.3 Mobile telecommunication infrastructure and its suitability for U-space

Mobile telecommunication networks could be the best solution to provide scalable connectivity solutions for U-space services and BVLOS operations in the future. Mobile telecommunication infrastructures/solutions for the U-space services should enable increased flexibility in the design and implementation of new types of services making reference to the U-space services requirements. The mobile telecommunication infrastructure should be capable of meeting appropriate U-space services performance requirements for coverage, quality of service, safety, security and reliability (resilience, failure modes, redundancy), while minimising environmental impacts and respecting the privacy and safety of citizens.

Current mobile telecommunication networks can already provide sufficient connectivity and enable U-space services in some environments and use cases. In the future, developed mobile telecommunication solutions for U-space services could enable scalable, flexible and adaptable services, also for demanding environments and use cases.

However, there are some challenges to meet to enable cooperation in the telecoms and aviation sectors. The telecoms industry providing the mobile telecommunication services is market driven. In addition, current commercial mobile networks are typically built and optimised for users on the ground. Large numbers of users in the air will cause interference to the mobile networks and users on the ground, if not implemented in a controlled manner. Coverage and service requirements are also not currently optimised for users in the air. Close cooperation between the two sectors is needed, firstly to understand the performance requirements that U-space services have of the mobile telecommunication services and, secondly, to develop a compromise on how the requirements can be met by the mobile telecommunication networks and services. The technical requirements of U-space services should be realistic and possible to meet in practice. This will also require developing new common business models for the cooperation between U-space and mobile telecommunication service providers.

U-space must be able to adapt to new communication technologies and automation, both ground-based and airborne, and increasingly allow for more advanced forms of interaction with the overall U-space ecosystem, predominantly through interoperable communication systems capable of digital information and data exchange such as the 5G mobile telecommunication infrastructure. Ultimately, the providers of the next generation of mobile telecommunication infrastructure must be persuaded to encompass the range of UAS/UAM demand, business models, applications and technologies, and to support safe and efficient U-space operations that also include manned aviation and existing ATM systems to ensure a fair and equitable access to the airspace.

Although mobile telecommunication networks can provide connectivity for many challenging environments and operations in the future, there will always be environments where mobile networks are not the optimal connectivity solution, such as high altitudes or remote locations.

D.3.3.4 Multiple U-space service providers

When U-space services, such as mission management or conflict management, are centralised, this can work relatively well (as there is one decision made by the ecosystem). The complexity comes when multiple USSPs have to exchange information and make collective/coordinated decisions that are consistent. Research needs to be carried out on specific use cases and safety-critical services that are impacted by this federated approach, for example tactical resolution services.

Solutions need to be developed that define the exchange of data between multiple USSPs and enable this vision of a federated U-space with multiple USSPs: failure management, discovery mechanisms, tracking (multiple sources) in a federated system and a common information service as the definition of standards for inter-USSP communication airspace. Equity and fairness principles are essential and, at the same time, they affect the service provision. This is related to the needs of data integrity and consistency within a fully federated U-space service architecture. Both may influence the VLL rules of the air.

Further R & D will be critical for the development of the multiple USSPs concept, addressing how conflicts will be resolved in a federated system, how authorisations will be provided in a multilayer environment, the reliability of communications in a in a federated system, the roles and responsibilities for the provision of services when several USSPs share the same portion of airspace and the requirements for a technical implementation of a fully federated U-space service architecture for unsegregated airspace.

D.3.3.5 Geofencing

Geofencing services are key components for U-space, which is why many SESAR projects have investigated them. In particular, the Geofencing for safe autonomous flight in Europe (GEOSAFE) project was fully dedicated to geofencing.

It should be ensured that:

- geoawareness has 'a single point of truth';
- geoawareness is efficiently distributed in a scalable way;
- the reactions of drones to a geofence are known or even standardised.
- When analysing the results from the flight trials, the following areas for further work were identified by specific projects:
- the need to integrate the geoawareness information into the drone's ground control station was commented on by several projects (SAFIR, SAFEDRONE, GOF U-Space and GEOSAFE);
- human factors associated with the safety-critical function of geoawareness need to be reinforced;
- GOF U-Space commented on an issue that the human–machine interface would have to deal with, either in a ground control station or in a planning tool: when a geofenced area is larger than the whole area being shown on the map (due to zooming in), then there is a risk that the person looking at the map might not understand that the entire map is covered by a geographic zone;
- SAFEDRONE commented on the need to use acoustic alerts for geoawareness.

D.3.4 Mapping of U-space service research

As a result of their research activities, the projects identified areas where further R & D is needed, impacting almost all the services, particularly for complex and dense environments.

FIGURE 24: AREAS WHERE FURTHER R & D IS NEEDED

R & D needs	Relevant U-space services
▶ Safety/risk assessment, including risks related to multiple drones interaction in the same area of operations) ▶ CARS, in particular addressing the vertical separation within VLL and with regard to manned aviation too *(Source: DIODE)*	▶ Airspace Management/geofencing ▶ Separation/conflict management ▶ Emergency management ▶ Monitoring ▶ Interface with ATC
▶ Definition of separation minima UAS/UAS and unmanned versus manned ▶ Tactical conflict resolution service integration WRT DAA airborne capabilities ▶ Interaction of dynamic geofencing with tactical geofencing/ conflict resolution service ▶ Analysis of U-space centralised architecture versus federated architecture performance *(Sources: DOMUS)*	▶ Separation/conflict management ▶ Interface with ATC ▶ Airspace Management/geofencing ▶ Monitoring ▶ Emergency management
▶ Automation of ATM to U-space interfaces, including linking with tracking and monitoring activities Integration of unmanned eVTOL WRT other AUs ▶ Onboard DAA with non-cooperative intruders Minimum separation distance among UAVs, taking into account their performance, systems on board, and mandatory flying dynamics ▶ CARS *(Source: EuroDRONE)*	▶ Interface with ATC ▶ Airspace Management/geofencing ▶ Separation/conflict management ▶ Emergency management
▶ Integration of U-space into eVTOL avionics eVTOL integration with regard to general and manned aviation ▶ High levels of automation and increased reliance on V2I, V2V and ATC/UTM communication links and cybersecurity *(Source GOF U-space)*	▶ Interface with ATC ▶ Airspace Management/geofencing ▶ Separation/conflict management ▶ Emergency management
▶ Conflict resolution capabilities and how to exchange flight plan data between the drone operation plan processing and operation plan preparation assistance services during the conflict management phase ▶ Definition of standards for inter-USSP communication without centralised services ▶ Impact of federated architecture on U-space services provision (e.g. for separation/conflict management). ▶ Data integrity and consistency within a fully federated U-space service architecture ▶ Weather information service in an urban scenario ▶ Monitoring and traffic information contingency scenarios ▶ Tactical deconfliction and dynamic capacity management services	▶ Airspace Management/geofencing ▶ Separation/conflict management ▶ Emergency management ▶ Monitoring

R & D needs	Relevant U-space services
▶ Conflict resolution capabilities and how to exchange flight plan data between the drone operation plan processing and operation plan preparation assistance services during the conflict management phase ▶ Definition of standards for inter-USSP communication without centralised services ▶ Impact of federated architecture on U-space services provision (e.g. for separation/conflict management). ▶ Data integrity and consistency within a fully federated U-space service architecture ▶ Weather information service in an urban scenario ▶ Monitoring and traffic information contingency scenarios ▶ Tactical deconfliction and dynamic capacity management services *(Source IMPETUS)*	▶ Airspace Management/geofencing ▶ Separation/conflict management ▶ Emergency management ▶ Monitoring
▶ UTM/GCS full integration (Source SAFEDRONE/GOF-USPACE) ▶ ATC/U-space interfaces ▶ Separation minima ▶ Common altitude reference system Telecommunications networks for U-space ▶ U-space services in urban or semi-urban environments ▶ Multi-USPs sharing the same portion of airspace responsibility for the provision of services (Source SAFEDRONE)	▶ Interface with ATC ▶ Airspace Management/geofencing ▶ Separation/conflict management ▶ Emergency management ▶ Environment
▶ Strategic and tactical deconfliction in a federated ecosystem ▶ Tactical deconfliction with regard to manned aviation ▶ Tracking (multiple sources) in a federated system ▶ Priority/emergency services ▶ Analysis of mobile telecommunication network for U-space (coverage, data integrity, authorisation, location based services…) ▶ Full testing, in all operational circumstances, of individual U-space services. ▶ Further in-depth testing and standardisation of U-space services in ground control station applications, (Source SAFIR)	▶ Emergency management ▶ Environment ▶ Separation/conflict Management
▶ Relevant CNS technologies for U-space services supported by them ▶ Conflict detection and tactical deconfliction (DAA) (Source TERRA)	▶ Separation/conflict management ▶ Relevant CNS services to support the required U-space services deployment
▶ Deconfliction strategy rules (Source USIS)	▶ Separation/conflict management
▶ Streamlining information exchange between USPs ▶ R&D and governances needs to be established at EU level in or to deliver/validate U-space. (Source VUTURA)	▶ Airspace Management/Geofencing ▶ Interface with ATC and other USPs
▶ Non-cooperative DAA solutions ▶ U-space reference communications backbone ▶ Further definition of the full set of U-space services and capabilities with an ad-hoc inventory (Source AirPASS)	▶ Separation/conflict management ▶ Relevant communication backbone services and performances to support U-space Services deployment
▶ Specific U-space reference communication backbone services (Source DROC2COM)	▶ Relevant communication backbone services and performances to support U-space Services deployment

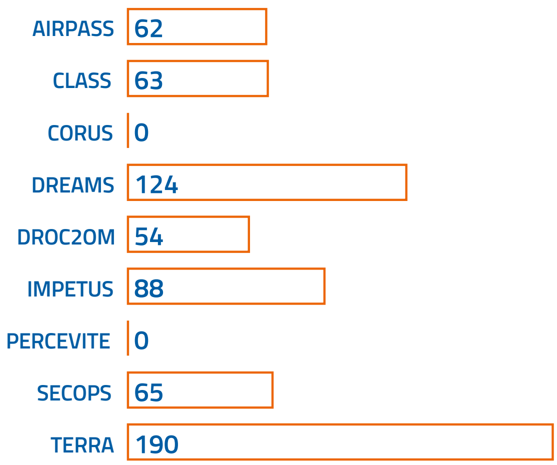
D.4 Performance requirements

In researching and demonstrating the U-space services, the SESAR JU projects identified an initial set of requirements in support of standardisation and regulation activities. These requirements are categorised according to minimum performance, level of safety, operational or technical interoperability, acceptability (privacy/noise) or security.

The development of these requirements is progressive and uses an iterative process. Each iteration leads to a baseline that provides a set of requirements mainly developed by the exploratory projects, and finally demonstrated by the projects performing flight trials. At the time of writing this document, the applicable baseline is baseline #3.

Figure 25 presents the number of requirements developed by each exploratory research project. Requirements produced by the CORUS project are not included. Inputs from the PercEvite project were not available in baseline #3 (this is expected in the next baseline).

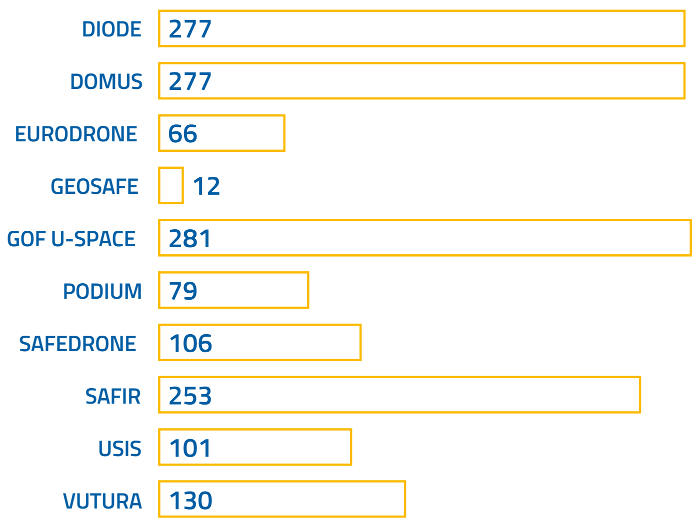
FIGURE 25: **NUMBER OF REQUIREMENTS PER EXPLORATORY RESEARCH PROJECT**



DREAMS, DRone European Aeronautical information Management Study; SECOPS, an integrated SECurity concept for drone OPerationS.

Figure 26 shows how the requirements have been covered in the demonstration activities. A requirement may be covered by more than one demonstration project. The number of requirements tackled by a project depends on its scope: GEOSAFE focused on geofencing, while the SAFIR, DOMUS and DIODE projects were more generic as they were focused on service provision in general.

FIGURE 26: **NUMBER OF REQUIREMENTS PER DEMONSTRATION PROJECT**



PODIUM, Proving Operations of Drones with Initial UTM.

A quality analysis was conducted to categorise the requirements and to assess their relevance (i.e. well defined and/or corresponding to services cited in the CONOPS – third edition) and value as input to standardisation/regulation work.

A scoring of their value was established – requirements with a score lower than six mainly correspond to the those that cannot be linked to the CONOPS.

Figure 27 indicates that a large part of the existing requirements are highly valuable, with almost 75 % of the requirements meeting the minimum level of quality (i.e. above X).

FIGURE 27: QUALITY ANALYSIS OF IDENTIFIED REQUIREMENTS

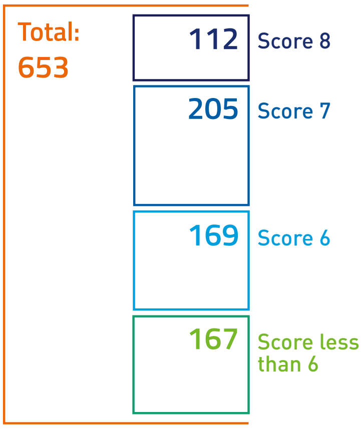


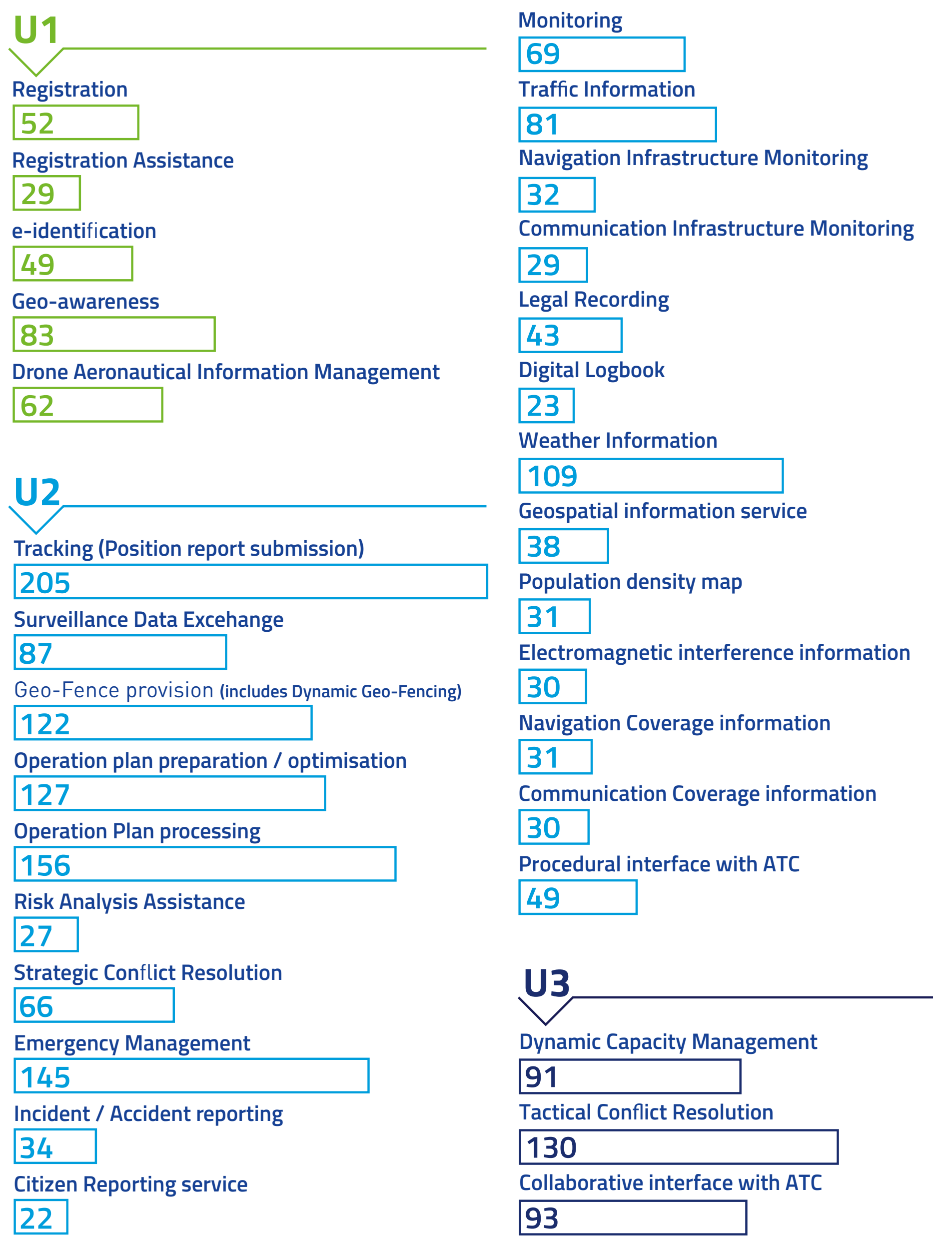
Figure 28 shows the distribution of all the requirements among the categories. A requirement may be allocated to more than one category. Consequently, the total number of allocated requirements (1 205) is higher than the total number of baseline #3 requirements (653).

FIGURE 28: CATEGORIES OF REQUIREMENTS

This view identifies the categories that could be strengthened in the future. In particular, 'acceptability' needs to be further addressed in terms of requirements

Finally, Figure 29 shows the allocation per service. A requirement may be allocated to one or more services. Consequently, the total number of allocated requirements (2 175) is higher than the total number of requirements (653).

FIGURE 29: NUMBER OF REQUIREMENTS PER SERVICE/CAPABILITY



The number of requirements allocated to U1, U2 and U3 services is, respectively, 275, 1 586 and 314 (13 %, 73 % and 14 %), which reflects the intensive focus on U2 services.

The projects have extensively addressed some services (tracking, plan processing, plan preparation/optimisation, etc.) with some omissions (e.g. citizen reporting).

To understand such variances, it should be noted that the projects started in 2017 and based their scoping on the services in the U-space blueprint. Throughout the CONOPS development (2017 to end of 2019), new services were progressively introduced; as a result, the most recently added were addressed to a lesser extent.

D.5 Standardisation and regulation

In addition to providing a breakdown of the development work still required, the SESAR results feed directly into the regulation and standardisation process under way in Europe, as well as in other world regions. Research findings and demonstrations provide valuable performance data to support coordinated and common standards for drone operations. For example, only by testing the performance of geofencing technology on board drones can appropriate minimum standards be drawn up. U-space demands a risk-based and performance-driven approach when setting up requirements for safety and security. This requires comprehensive understanding of the performance of drones in operational scenarios.

U-space implementation is dependent on the available technologies and the use of harmonised standards, as well as the maturity of the U-space services. These services are scaled to integrate drones' operations in the airspace and to enable them to operate together with manned aircraft, in a safe, efficient and sustainable manner. The findings from the SESAR JU projects pave the way for this implementation and for the required standards, protocols and regulations. An initial conclusion is to use and maintain the U-space CONOPs developed by CORUS as the common reference for future validation, regulation and/or standardisation activities.

Another key conclusion of the projects is the need to support the standardisation process by collecting data. This need for data is essential to elaborate the necessary minimum operational performance standards for U-space services' equipment/systems and capabilities, as well as for drones. The data are also needed for the enabling infrastructure to be set to support U-space operations. Those performances have to be commensurate with the traffic and traffic complexity to ensure the safety of operations.

This could be done through the development of a number of R & D projects that focus on large-scale demonstrations of cooperative and non-cooperative traffic, and of manned and unmanned traffic. These demonstrations should be large-scale scenarios with tens, hundreds or even thousands of participating drones and USSPs, and the implementation of flight corridor testing and hardware and software robustness testing. Regarding security, penetration testing of U-space services must be organised by an independent party: an ethical hacking approach for testing the implemented security measures of a U-space service would be beneficial. In addition to the minimum operational performance standards, these R & D activities will be the basis for the development of acceptability criteria and best practices needed to support all the open-source or proprietary developments done in parallel.

From the experience gained from the demonstration projects, it can be concluded that, until advanced services are developed, U-space services supporting strategic conflict management are key for the functioning of initial U-space airspace implementations. The operation risk assessment to consider air collisions also needs to be updated to ensure safe implementation.

Guidance material needs to be developed to support the application of the regulation, including a common terminology and a clear definition of roles and responsibilities. This addition to the existing regulation will support the safe management of the traffic.

As U-space is about the safe integration of drones in the airspace, project conclusions and recommendations on standardisation and regulation naturally fall in the safety area. A common and unique method of exchanging information needs to be shared between all involved stakeholders, whether they are manned or unmanned, clarifying the information and data required to access an airspace managed by U-space. One piece of information that must be shared, in a cooperative way, between the airspace users is the traffic information.

This information-sharing goes with data exchange. In this respect, standards are required related to protocol, data models, interfaces and services behaviour, time synchronisation method, encoding mechanisms and failure modes. Standards must also be developed related to the notion of a single source of truth. Specific privacy standards are also needed, particularly with drones under BVLOS operations. Current privacy and data protection laws and rule-making, including e-identification and tracking, are to be further developed.

Finally, having multiple service providers acting in the same geographical area at the same time requires coordination procedures between them (USSPs and ATS providers). Such procedures will enable interoperable, safe and secure operations across Europe. A special emphasis on the coordination between ATS and USSPs will contribute to the safe management of traffic in all airspace classes. Other concerns specific to the multiple USSPs have been identified by the projects, one example being the need to develop standards for a 'USSP discovery' mechanism.

D.6 U-space services catalogue

D.6.1 Identification and tracking

D.6.1.1 Registration and registration assistance services

The registration service allows drone operators to access the registry, to register or update their entries, as is required by law. The registration service also allows law enforcement agencies or other authorised users to retrieve operator details.

The registration assistance service is a user-friendly assistance for some specific registrations that occur routinely, for example allowing a shop owner to register a new drone operator when a drone is sold, or a training school to register pilots for training.

Figure 30 lists the requirements for the implementation of these services that were identified by the IMPETUS and TERRA projects.

FIGURE 30: **REGISTRATION SERVICE REQUIREMENTS (NON-EXHAUSTIVE)**

Title	Description
e-registration	The operator shall complete the e-registration process before starting operations.
Registration process	The system shall facilitate the storage of registration information about drone/pilot/operator in a national/local database. The registration information contains at least an electronic identifier to link the e-registration and the e-iIdentification.
e -registration validation	The relevant national authority should confirm what the drone/operator/pilot is allowed to fly when submitting the registration acknowledgement.
Authorisation acknowledgement	The system should confirm what the drone/operator/pilot has been allowed to fly by the authority, when submitting the registration acknowledgement.
e- registration validation	The authority shall provide an e-registration certificate.
User profiling	The system shall allow user profiling: restricted content and functionalities will be accessible depending on the profile of the authenticated user. Access to each content and function type must be configurable by the supervisor.
Registering information for law enforcement agencies	Law enforcement units shall be able to access drone/operator/pilot registration information when required.
Provision of pilot location and operator contact details to law enforcement units	The system shall provide pilot location and operator contact details for drones in flight to law enforcement agencies when required.
Drone capabilities e-registration	To develop complex operations (e.g. Urban, BVLOS, etc.), the operator shall register drones capabilities and sensors.

D.6.1.2 Remote identification and e-identification service

Broadcast remote identification is a drone capability that allows operators or authorities nearby to receive some information about the drone and its operator. The network remote identification service allows a drone to be identified by comparing the position reported by the observer with the known position as tracked by U-space.

The e-identification service is used primarily, but not only, by law enforcement agencies. It takes the remote identification information and uses it to retrieve operator details from the registry and operation details from a set of current and known operations. A simpler version of the service, which protects the privacy of the drone operator, is expected for public use.

Figure 31 lists the requirements for the implementation of these services that were identified by the AIRPASS, DREAMS, IMPETUS and TERRA projects.

FIGURE 31: **IDENTIFICATION SERVICE REQUIREMENTS (NON-EXHAUSTIVE)**

Title	Description
Electronic identification of drones for territory control	In the interest of public security and safety, law enforcement agencies shall be able to identify with a dedicated portable equipment any flying drones.
Provision of e-identification information to law enforcement agencies	Law enforcement agencies shall be able to access to e-identification information about drones in flight when required.
Pilot location and operator contact details to law enforcement agencies	Law enforcement agencies shall be able to access to pilot location and operator contact details for drones in flight when required.
Provision of drone' location information to law enforcement	In urban areas or near to critical infrastructure, law enforcement agencies shall be able to have continuous up-to-date information about drones' location, linked to e-identification and e-registration data.
E-identification	The system should process the electronic identifier code received together with the tracking message (position and time stamp) and link them to the e-registration assigned to a drone, allowing unique identification of drones in flight.
Registering information data provision	The system will provide e-registration information relative to a certain drone in flight detected by the system to authorised users (e.g. all useful information to law enforcement agencies)
Continuous operator contact data	Drone pilot location or operator contact details shall be registered and available by the system during the whole flight.
Profiling of data visualisation-operator contact	The system shall provide drone or pilot location and operator contact data relative to a certain drone in flight presented in the map, when requested by a supervisor or other authorised user (e.g. Law enforcement unit).
Communication for e-identification	The on-board system shall provide a physical data link and a protocol to identify the UAS and UAS operator in U-space services from power-up or first movement until landing.
Navigation for e-identification	The on-board system shall provide position information (including accuracy and integrity) of UAS for initialisation of U-space services.
Flight control functions for e-identification	The on-board flight control system shall trigger the transmission of e-identification messages upon power-up or first movement.
Database for e-identification	For identification, a unique identifier shall be stored on board the UAS in a database. Optionally this identifier contains UAS information like UAS class, equipment list, technical data (including minimum and maximum airspeed, manoeuvrability for deconfliction information), purpose, manufacturer and operator.
Drone identification and tracking information broadcast	The drones shall broadcast tracking messages (i.e. positioning) to allow the system calculating the position of every drone linked to its e-identification.
E-identification should be linked with e-registration	E-identification data should not rely on a flight plan for identification data. E-identification should rely on e-registry data.

D.6.1.3 Tracking, position report submission and surveillance data

For some drone operations, the identity and position of the drone must be reported to U-space at regular intervals to allow tracking, a network remote identification and other services. The position report submission subservice allows the drone operator to send position reports to U-space, and associates them with a particular drone operation. The subservice may be provided with reports by different means, for example from a remote-piloting station or from a tracking service offered by a telecoms provider. The subservice includes start-of-flight and end-of-flight messages. The subservice gives feedback that the reports are being received correctly.

The tracking service generates a track for the operation and is an enabler for services that are based on the current position and motion of the drone, such as conformance monitoring, traffic information, tactical conflict resolution and network remote identification. Tracking depends on position reports sent by the position report submission subservice, but combines other sources such as drone detection systems, if any are available. The tracking service will provide both tracks and an indication of the uncertainties associated with these tracks. The extent of these uncertainties will determine what can be done with the track information, or the margin that must be applied when the track is used. The technical requirements associated with some airspace volumes will often be in terms of tracking performance.

The surveillance data service supports exchanges between the tracking services and other sources or consumers of tracks, such as ATC or drone detection systems.

Figure 32 lists the requirements for the implementation of these services that were identified by the CLear Air Situation for UAS (CLASS), DREAMS, GOF U-space, IMPETUS and TERRA projects.

FIGURE 32: **TRACKING SERVICE REQUIREMENTS (NON-EXHAUSTIVE)**

Title	Description
Communication for tracking	The on-board system shall provide a data link and a protocol to track the UAS by U-space services from start-up to landing, and providing the data on the position, time stamps (and their accuracy), altitude and velocities, and any expected changes in velocity and direction. A label with the drone's identity shall be included.
Communication for tracking	The on-board communication system for tracking purposes shall be reliable, stable and secure.
Navigation for tracking	The on-board system shall provide position information (equivalent to latitude, longitude, height ([1])), should provide velocity and direction information and could provide upcoming changes (due to flight planning) in velocity and direction.
Track ID	The tracking service shall provide each track by a unique ID number. In case the target is unknown, the ID number may be arbitrary. In case the track drones carries a cooperative tracker, the tracks shall carry the drone-ID.
Indication of track source	The UTM system shall indicate the different track sources via a label on the vehicle to ensure correct monitoring of different tracks
Interface with trackers	The UTM system shall interface with the drone to obtain: ▶ Non-cooperative tracks ▶ Cooperative tracks ▶ Fused tracks
Helicopters/VFR traffic position	The system should be able to receive tracking messages sent by helicopters/VFR traffic flying in areas where drones traffic is allowed.
Helicopter/manned aviation position	The system should be able to calculate the position of helicopters/VFR Traffic flying in areas where drone traffic is allowed, using the tracking information sent by them or an ATM system.
Drone identification broadcast and independent tracking processing	Above critical areas (airports, national security facilities, mass events, etc.), law enforcement shall be able to obtain drones' positions calculated independently from the tracking information provided by the drones.

Direct interface with non-cooperative tracker	The UTM system shall interface directly with the non-cooperative tracker.
Non-cooperative tracking data minimum content	The non-cooperative tracking device shall transmit for each tracked target classified as a drone the track ID, target category, 3D position and timestamp.
Continuity requirement for tracking	The tracking service shall deliver information with a continuity (Max tolerable probability of interruption of service per flight/hour) equal to 1E-05.
Drone identification broadcast and independent tracking processing	Above critical areas (airports, national security facilities, mass events, etc.), law enforcement shall be able to obtain drones' positions calculated independently from the tracking information provided by the drones.
Non-cooperative classification latency	The non-cooperative tracker shall classify the target in less than 8 seconds from track initiation.
Data fusion tracker detection performance	The data fusion tracker should achieve a probability of update >90 % for the specified drone types over the required coverage area
Data fusion latency	The data fusion tracker will declare the target classification in <6 seconds from track initiation
Technology agnostic	Tracking is technology agnostic (successfully demonstrated based on [existing technology:] Scanning surveillance radar (SSR), ADS-B, FLARM, mobile network trackers and telemetry (ground control station – GCS – integration) [and open to any new technology])
Altitude reference	Recommend standardising the treatment of altitude references, such as above take-off location (ATO, also known as QFE), above elevation data (AED), above mean sea level (AMSL), QNH or QNE (FL).

D.6.2 Airspace management and geofencing

The geoawareness service provides geofence data for use by the drone operator, pilot and the drone itself. The geofence data are delivered in a standard format that can be interpreted by operation plan preparation optimisation tools and services. The geofencing provision service extends this and provides capable drones and remote pilot stations directly with geofences, even during flight. The drone aeronautical information management service allows authorised organisations to create, update or remove geofences and other geographic data at any time.

Figure 33 the requirements for the implementation of these services that were identified by the DREAMS, IMPETUS and TERRA projects.

FIGURE 33: GEOAWARENESS REQUIREMENTS (NON-EXHAUSTIVE)

Title	Description
Temporary segregation of area	The tactical geofencing service shall enable authorised users to segregate areas dynamically and temporarily.
Dynamic geofencing	The dynamic geofencing system shall provide drone operators and users with coordinates of dynamic geofence polygons with a minimum accuracy level of 1 metre.
Safety requirements for U-space service providers deriving from specific operational risk assessment (SORA)	In accordance with SORA Annex E, the provision of external services (as the U-space services) shall comply with safety requirements. The higher the SAIL, the most demanding are these requirements. For operations dealing with SAIL IV, service providers shall be subject to oversight mechanisms (a competent third party shall be involved).
Transaction time requirement for pre-tactical geofencing	The pre-tactical geofencing service shall deliver information with a maximum transaction time of 120 seconds.
Continuity requirement for pre-tactical geofencing	The pre-tactical geofencing service shall deliver information with a continuity (max tolerable probability of interruption of service per flight/hour) equal to 1E-02.

Availability requirement for pre-tactical geofencing	The pre-tactical geofencing service shall deliver information with an availability (max tolerable probability of non-availability of service per flight/hour) equal to 1E-02.
Integrity requirement for pre-tactical geofencing	The pre-tactical geofencing service shall deliver information using a software with a minimum design assurance level (DAL) equal to C.
Transaction time requirement for tactical geofencing	The tactical gefoencing service shall deliver information with a maximum transaction time of 10 seconds.
Continuity requirement for Tactical Geofencing	The tactical gefoencing service shall deliver information with a continuity (max tolerable probability of interruption of service per flight/hour) equal to 1E-05.
Availability requirement for tactical geofencing	The tactical gefoencing service shall deliver information with an availability (max tolerable probability of non-availability of service per flight/hour) equal to 1E-05.
Integrity requirement for tactical geofencing	The tactical gefoencing service shall deliver information using a software with a minimum DAL equal to B.
Human-machine interface	Geofencing information should be received and displayed through by the ground control station so as enhance human performance and to allow for automation.

D.6.3 Mission management

D.6.3.1 Operation plan processing, operational plan preparation and optimisation and risk-analysis assistance services

An operation plan gives a detailed description of a flight by a drone, stating who will fly what, where and when. This is mandatory in some airspace volumes – the flight can occur only if the plan is approved. The operational plan preparation and optimisation service helps the drone operator to prepare an operation plan and submit it to U-space. The service should present the operator with relevant information for their business needs, such as maps or trajectories optimised for their own fleet. The operation plan processing service receives the plan and then replies with approval or an explanation of why approval has not been given. The operation plan processing service is the gateway to a number of other services that are based on the operation plan, such as the strategic conflict resolution service. The operation plan processing service also allows the operator to change or cancel the operation plan. A risk-analysis assistance service can be used to check an operation plan against environmental data (population density, communication coverage, etc.) to support SORA or 'per flight insurance' services.

Figure 34 lists the requirements for the implementation of these services that were identified by the DREAMS, IMPETUS, TERRA and GOF U-space projects.

FIGURE 34: **MISSION MANAGEMENT REQUIREMENTS (NON-EXHAUSTIVE)**

Title	Description
Main capabilities of flight planning management service during flight plan submission	The flight planning management service shall act as the U-space 'front end' for drones and drones users. During the flight plan submission the most relevant information shared with the U-space front end (flight planning management service) will include: drone Identification and capabilities, drone user identification; drone position and height, and time of operations; and drone capabilities and settings.
Mission request contact information	The mission request shall include operator and pilot contact data, which must be available during the flight.
Mission request volume of operation	The mission request shall include a definition of the desired trajectory or the volume for the operation.
Mission request approval	The operator shall be able to submit a request to fly in a certain piece of airspace (mission request).
Mission request approval	The operator shall receive a mission plan approval before the flight is started.

Mission validation or automatic alternative mission proposal	If the requested trajectory is not feasible, the operator shall be advised by the system about all the constraints (including, at least, other drone trajectories, drone/pilot capabilities, risk to third parties, geofenced areas, restrictions, controlled airspace and forbidden areas) and, if possible be provided with a feasible alternative trajectory.
Flight plan update	The MPM service shall report every update of the individual flight plan status from the FPM service to the drone operator.
Flight plan conflict notification	The FPM service shall notify the MPM service when a conflict emerges with the initially approved flight plan and provide with an explanation about the issue
Flight plan transmission	The MPM service shall transmit the flight plan to the FPM service in a common format.
Flight plan re-submission	The FPM service shall allow the MPM service to modify the flight plan and re-submit it.

D.6.3.2 Dynamic capacity management service

Strategic and tactical conflict resolution services reduce the probability of collision to a residual level, albeit not to zero. As the number of operations planned in a volume of airspace rises, so do the cumulative residual risks of conflict. When the residual risk reaches the maximum acceptable level, then capacity is reached. The dynamic capacity management service calculates this residual risk and detects when capacity is reached. It then either takes measures to provide more capacity or to limit the traffic. The dynamic capacity management service is one of the services that approves an operation plan submitted to the operation plan processing service.

Figure 35 lists the requirements for the implementation of these services that were identified by the DroC^{2}om, DREAMS, IMPETUS and TERRA projects.

FIGURE 35: **DYNAMIC CAPACITY MANAGEMENT REQUIREMENTS (NON-EXHAUSTIVE)**

Title	Description
Flight plan approval process	The FPM service shall only approve the flight plan after validation through the deconfliction and the airspace capacity management functions.
Area density	During the validation phase, the system should take into account the availability of the area, considering all the missions within the same space/time horizon
Datalink interoperability	The C2 link system underlying network shall support interoperability with multiple ground operators and multiple communication service providers simultaneously.
Approved mission plan modification	The operator shall receive alerts about modifications and updates of the approved mission plans when they have to be adapted due to new restrictions (geo-fenced areas, etc.) or optimisation of trajectories to increase capacity.

D.6.4 Conflict management

D.6.4.1 Strategic and tactical conflict resolution services

There are two services for conflict management in U-space: strategic conflict resolution, which occurs before take-off and resolves conflicts in the planned operations, and tactical conflict resolution, which resolves conflicts that are detected during the flight.

The strategic conflict resolution service is initiated by the operation plan processing service. It can be initiated when a new operation plan has been submitted or when an already submitted operation plan has changed. Strategic conflict resolution occurs before take-off. In detection, the service compares the probabilities of where each aircraft will be at each moment in time. A conflict can be resolved by asking the operator of one flight to change the plan and propose conflict-free alternative trajectories.

Tactical conflict resolution resolves conflicts detected during flight and can be offered only if the positions and movements of all aircraft are known by the tracking service. The tactical conflict resolution service is activated following the strategic conflict resolution, which solves low-probability conflicts before flight, for example changes in the aircraft trajectory due to wind. The performance of the tactical conflict detection service depends on the accuracy of the data provided by the tracking service.

Figure 36 lists the requirements for the implementation of these services that were identified by the DREAMS, IMPETUS, CLASS and TERRA projects.

FIGURE 36: STRATEGIC AND TACTICAL CONFLICT RESOLUTION REQUIREMENTS (NON-EXHAUSTIVE)

Title	Description
Strategic deconfliction capabilities	The strategic deconfliction service shall capable of detectiing conflicts between flight plans and of proposing reasonable modifications to the flight plan to the flight planning management service (alternative flight plan, different time slot,…).
Flight plans information kept in strategic deconfliction service	The strategic deconfliction service shall have access to a cloud data base (or other distributed structures) where all the known flight plans are stored.
Impact of Flight planning management, Pre-Tactical Geofencing, Tactical geofencing and Emergency Management services on SORA based-risk assessment.	Flight planning management, pre-tactical geofencing, tactical geofencing and emergency management services shall be used as M3 mitigation to the ground risk in SORA.
Safety requirements for U-Space service providers deriving from SORA assessment.	In accordance with SORA Annex E, provision of external services (as the UTM services) shall comply with safety requirements. The higher the SAIL, the most demanding are these requirements. For operations dealing with SAIL IV, service providers shall be subject to oversight mechanisms (a competent third party shall be involved).
Integrity requirement for strategic deconfliction	The strategic deconfliction service shall deliver information using a software with a minimum design assurance level (DAL) equal to B.
Vertical separation in VLL airspace	The U-space shall ensure a common reference frame for vertical separation of drones in VLL airspace.
Alternative flight plan	The flight planning management service shall propose alternative routes to users in case of conflicting plans due to changes in the environmental conditions.
Mission plan status accessibility	The operator shall have access to the system before starting the flight to confirm that the accepted route is still valid or if there has been any modification.
Trajectory alerts processing for pre-tactical de-confliction	The operator shall receive alerts to modify drone trajectories in order to avoid potential conflicts with other drone operators or manned aviation.
Mission Request privacy of information provided	The system shall not show information about other drone operators.
Area density	During the validation phase, the system should take into account the availability of the area, considering all the missions within the same space/time horizon.
Raise conflict alert	The conflict detection service shall raise conflict alerts to drone operator 1 and 2 based on the deconfliction functionality.
Mission plan status accessibility	The operator shall have access to the system before starting the flight to confirm that the accepted route is still valid or if there has been any modification.

D.6.4.2 Emergency management service

The emergency management service of U-space has two aspects:

- giving assistance to a drone pilot experiencing an emergency with their drone;
- communicating emergency information to the drone pilot, for example that there is danger nearby or that some function of U-space is impaired.

The communications channel of the emergency management service is an essential safety feature as it is the only way to deliver emergency messages to the drone operator.

Figure 37 lists a small number of the many requirements common to these services and developed by the DREAMS, IMPETUS, DroC^{2}om and TERRA projects.

FIGURE 37: **EMERGENCY MANAGEMENT REQUIREMENTS (NON-EXHAUSTIVE)**

Title	Description
Emergency communication submission	The operator shall be able to communicate emergencies to the system in real time.
Operator/Pilot /Drone communication performance	Drone pilot/operator shall be continuously connected to the system to know if their drone has to land in case of emergency flight, using an APP or by cellular.
Temporary segregation of area	The tactical geofencing service shall enable authorised users to segregate areas dynamically and temporarily.
Alerts to drone operators	Drone pilots/operators shall receive alerts to land or modify their trajectory in case a manned aircraft is operating near them.
Bounding volume for emergency procedures	The traffic information service shall extend the information area for a certain operation in cases where emergency procedures have been activated in the surroung airspace.
Approved mission plan modification	The operator shall receive alerts about modifications and updates of the approved mission plans when they have to be adapted due to new restrictions (geo-fenced areas, etc.) or optimisation of trajectories to increase capacity.
Weather updated information	Sudden local weather changes should be notified to operators to mitigate potential risks.
Detection of loss of information periods	The role in charge shall be able to detect periods in which the information is not available and raise and alert that will scale to the Orchestrator, which will be in charge of activating the emergency procedure.
Flight control functions for emergency management	The on-board flight control system shall be able to perform risk mitigating activities like flight termination or mission abortion on request of U-space services immediately. Ground control station and U-space services should be informed accordingly.

D.6.4.3 Accident and incident reporting and citizen reporting services

Accidents and incidents for drones are reported in the same way as for manned aviation. The U-space accident and incident reporting service supports the standard aviation process for accident/incident reporting, tailored for the drone user. Not all incidents will be investigated but the collection of statistics is in the general interest. Similar to the accident and incident reporting service, U-space should allow citizens to report what they have observed when they believe incidents or accidents involving drones have occurred via a citizen reporting service.

Figure 38 lists some requirements common to these services and developed by the DREAMS, IMPETUS and TERRA projects.

FIGURE 38: **REPORTING REQUIREMENTS (NON-EXHAUSTIVE**

Title	Description
Provision of drone location information	The system shall provide registered tracks to law enforcement or aviation authorities, when required.
Provision of registeration information	Law enforcement agencies shall be able to access drone/operator/pilot registration information when required.
Provision of mission plan information	Law enforcement agencies shall be able to access mission plans when required.
Tracking logging	The tracking service shall log all the data for at least one month.
User profiling	The system shall allow user profiling: restricted content and functionality will be accessible depending on the profile of the authenticated user. The accessibility of each content and function must be configurable by the supervisor.
Connectivity	The selected communication infrastructure shall provide connectivity between the central system and all nodes.

D.6.5 Monitoring

D.6.5.1 Monitoring and traffic information services

The monitoring service warns the remote pilot and/or drone operator if the drone is not following its operation plan. The warnings are based on information coming from the tracking service and the operation plan processing service. As operation plans will be deconflicted before flight, monitoring that the operation plans are followed is a safety-critical service. In the same way, monitoring feeds the tactical deconfliction with critical information. The traffic information service, which is also based on the tracking service, provides the drone pilot and/or operator with information and warnings about other flights – manned or unmanned – that are expected to come near their aircraft. The traffic information service will also present the ‘air situation’ graphically.

Figure 39 lists some requirements common to these services that were developed by the AIRPASS, DREAMS, IMPETUS, CLASS and TERRA projects.

FIGURE 39: **MONITORING REQUIREMENTS (NON-EXHAUSTIVE)**

Title	Description
Trajectory alerts reception	In case the flight is going to be conducted in a volume that cannot be geocaged for the user, the operator shall be alerted if a minimum separation distance with other drones cannot be maintained, to guarantee that the risk of collision is negligible over populated areas and low enough in sparsely populated areas.
Pilot accessibility to nearby unmanned traffic information	Operators shall be able to receive the location of nearby drones and other aircraft, although not their private data (Traffic Information), to improve situational awareness.
Geographical extension of the information	The traffic information service shall provide all the relevant information about traffic within a geographic bounding volume dimensioned large enough to ensure the safety of all the operations contained within.
Bounding volume for emergency procedures	The traffic information service shall extend the information area for a certain operation in case of emergency procedures has been activated in the surroundings of its bounding volume.
Mission Request privacy of information provided	The system shall not show information about other drone operators.
Traffic information to operators	In urban or high drone density areas, the system should provide traffic information to operators to allow adequate situational awareness.
VFR information	The system should provide information of geo-caged areas to VFR aviation.
Monitoring	The system shall allow monitoring of the functional status of each capability.
Display of the flight track of drones	The UTM system shall display the tracks of the drones to: - other drone operators - The authority responsible for the area
Front end track filtering	The UTM system shall filter the tracks to show: - Non cooperative tracks - Cooperative tracks - Fused tracks - A combination of the upper
Maximum allowed latency in UTM system of 1 second	The UTM system shall show all the data (positions, tracks, zones, alerts,…) with a maximum latency of 1 second.

D.6.5.2 Legal recording and digital logbook services

The legal recording service supports accident and incident investigation. The service should record all inputs to U-space and allow the full state of the system at any moment for post-analytical purposes. In view of the commercial sensitivities of drone operators, access to the recordings will be restricted. The digital logbook service extracts some information from the legal recordings. Drone operators and pilots will be able to see summaries and statistics for flights they have been involved in.

Figure 40 lists some requirements common to these services and developed by the DREAMS, IMPETUS, CLASS and TERRA projects.

FIGURE 40: RECORDING SERVICES REQUIREMENTS (NON-EXHAUSTIVE)

Title	Description
Data recording and auditing	The service shall record all activity. All activity must be recorded for post analytical review, this includes all inputs, analysis, and rerouting decisions and commands.
Provision of location information to authorities	The system shall provide registered tracks to Law Enforcement or aviation authorities, when required.
Provision of mission plan information to law enforcement agencies	Law enforcement agencies shall be able to access mission plans when required.
User profiling	The system shall allow user profiling: restricted content and functionality will be accessible depending on the profile of the authenticated user. The accessibility of each content and function must be configurable by the supervisor.
Mission plan information to Law Enforcement agencies	The system shall provide access to Mission Plans to Law Enforcement agencies when required.
Provision of drone log access to authorities	The system shall provide access to drone logs and registered tracks to law enforcement and aviation authorities.
Tracking logging	The tracking service shall log all the data for at least one month.

D.6.5.3 Navigation and communication infrastructure monitoring services

The navigation infrastructure monitoring service provides status information about navigation infrastructure such as GNSS. The pilot and/or operator uses this service before and during operations. The service should give warnings of loss of navigation accuracy. The communication infrastructure monitoring service provides status information about communication infrastructure such as the mobile telephony networks. The pilot and/or operator uses this service before and during operations. The service should give warnings of current or predicted degradation of communications, for example scheduled maintenance.

Figure 41 lists some requirements common to these services and developed by the DREAMS, IMPETUS and TERRA projects.

FIGURE 41: INFRASTRUCTURE MONITORING REQUIREMENTS (NON-EXHAUSTIVE)

Title	Description
Integrity alerts	The operator should receive alerts if the navigation system is not able to provide an accurate position.
Monitoring	The system shall allow monitoring of the functional status of each capability.
Connectivity	The selected communication infrastructure shall provide connectivity between the central system and all nodes.
Safety requirements for U-Space service providers deriving from SORA assessment.	In accordance with SORA Annex E, provision of external services (as the UTM services) shall comply with safety requirements. The higher the SAIL, the most demanding are these requirements. For operations dealing with SAIL IV, service providers shall be subject to oversight mechanisms (a competent third party shall be involved).

D.6.6 Environment

D.6.6.1 Weather information service

The weather information service provides current and forecast weather information relevant to drone operation. The service should include hyperlocal weather information when available and required.

Figure 42 lists some requirements common to these services and developed by the DroC^{2}om, DREAMS, IMPETUS and TERRA projects.

FIGURE 42: **WEATHER INFORMATION SERVICE REQUIREMENTS (NON-EXHAUSTIVE)**

Title	Description
Weather information accessibility	The operator shall have access to weather information when preparing the mission plan to confirm that meteorological conditions are acceptable for the flight.
Hyperlocal weather information	The weather management system shall provide drone operators and users with minute-by-minute hyperlocal weather data.
Local-scale weather information aspects to be provided	The local-scale weather information service shall provide a configurable combination of the following weather information: ▶ Weather information provider ID [unique identifier] ▶ Look-ahead type [nowcast/forecast] ▶ Data generation time [Julian date & time of data generation] ▶ Applicability timeframe [period of time of data applicability since data generation] ▶ Temperature [K] ▶ Pressure [Pa] ▶ Icing [% probability] ▶ Visibility [m] ▶ Precipitation [{ % probability, type}; type: (freezing) rain/sleet/snow] ▶ Convective precipitation [% probability] ▶ Lightning [% probability] ▶ Average wind (u,v,w) [m/s] ▶ Turbulence [Turbulent Kinetic Energy (TKE) m2/s2] ▶ Gusts [frequency spectrum of specific kinetic energy J/kg] ▶ Thermals [% probability] ▶ Forecast/nowcast uncertainties [STD associated with data items 5) to or such data items are N-tuples, N being the number of members of an ensemble meteorological forecast/nowcast] ▶ Reminders, warning and alerts [new dataset available, expiration of applicability timeframe, data items 5) to 15) exceeding predefined thresholds or nowcasted data items 5) to 15) deviating from the forecasted versions of the same data items beyond the estimated uncertainty]
Geospatial domain	The weather information provided by the service shall correspond to the geographical domain specified by the petitioner. To specify such domain, the service shall provide the following geospatial primitives: 1) Geolocation [geodetic longitude, latitude and altitude in a geodetic reference system, e.g. WGS-84]; 2) Geocube [interval of geodetic longitudes, latitudes and altitudes in a geodetic reference system]; and 3) Geoprism [base geopolygon plus interval of altitudes in a geodetic reference system]which the petitioner can instantiate to make the petitions of weather information.
Impact of Weather information service on SORA based-risk assessment.	Weather information service shall be taken into account in the threat barrier named 'Environmental conditions for safe operations defined, measurable and adhered to ' (SORA Annex E).
Weather updated information	Sudden local weather changes should be notified to operators to mitigate potential risks.

Transaction time requirement for weather information	The Weather information service shall deliver information with a maximum transaction time of 10 seconds.
Mission planning management – data visualisation	The MPM service shall visualize the types of information to the operator that are relevant for mission planning.
Supported weather conditions	The system should inform if the weather conditions could not be supported by the drone, considering its features.

D.6.6.2 Geospatial information, population density map, electromagnetic interference information, navigation coverage information and communication coverage information services

A number of services provide the current and forecast data needed in planning and operating in VLL, as well as supporting SORA. Each meets agreed standards for quality including timeliness and accuracy. The geospatial information service assembles and provides map data relevant to operation in VLL describing terrain, buildings and obstacles. The population density map service collects and forecasts population density, which is used to assess ground risk. The information should be based on proxies for instantaneous population density, such as mobile telephone density. The electromagnetic interference information service delivers reports and forecasts of electromagnetic interference that is relevant for drone operation; typically, such interference hampers communications, navigation or the operation of sensors or the drone itself. The navigation coverage information service provides maps showing measured and forecast information about the navigation coverage, indicating where performance is reduced. These maps may be specialised depending on the navigation infrastructure available (e.g. ground or satellite based). The communication coverage information service provides maps indicating reported and expected communication coverage by service or provider, as far as it is known. This service is used to plan operations.

Figure 43 lists some requirements common to these services and developed by the DREAMS, IMPETUS and TERRA projects.

FIGURE 43: **MAP-BASED SERVICES (NON-EXHAUSTIVE)**

Title	Description
Geospatial information	The service shall programmatically access geospatial information to enable drones to carry out safe operations. The data set should include both airborne and ground hazards. Therefore the service requires access to geospatial data, which needs to include some or all of the following; ground hazards, obstacles, terrain, city maps, etc., in addition to airspace restrictions such as airspace classifications.
Terrain model service	The U-space shall provide geographic information services to users with digital cartographic information and digital elevation model. The proposed accuracy of the model is 1 metre (horizontal and vertical). The proposed resolution of map is 0,5 metre.
Obstacle information	The flight planning management system shall provide obstacle data with a minimum resolution of 1m (both horizontal and vertical).
Vertical separation in VLL airspace	The U-space shall ensure a common reference frame for vertical separation of drones in VLL airspace.
Mission planning Management – data visualisation	The MPM service shall visualise the types of information to the operator that are relevant for mission planning
Flight plan approval	A flight conformance module built in the FPM service shall be the instance responsible for approving or rejecting the individual flight plans based on defined rules and prioritization criteria.

D.6.7 Interface with air traffic control

The procedural interface with ATC is a service to coordinate an entry/exit of a flight into/from controlled airspace. The interface works before the flight. The operation plan processing service will invoke the service and through it:

- ATC can accept or refuse the flight;
- ATC can describe the requirements and process to be followed before and during the flight.

The collaborative interface with ATC is a service providing communication between ATC and the remote pilot, or the drone itself in the case of automatic flight. The service is used when the drone is in a controlled area and allows flights to receive instructions and clearances in a standard and efficient manner.

An example involving both would be a drone flight that starts and ends in uncontrolled airspace but during the flight crosses an airport (controlled airspace). The operation plan would trigger the procedural interface with ATC, who would either respond with a standard set of instructions or combine that with a process to give approval for the flight. The standard instructions might be to fly to some particular point and then hover or circle and contact the tower by telephone. If a collaborative interface with ATC were available, the instructions given with the plan approval would involve using the collaborative interface to coordinate with the tower. The collaborative interface would enable the tower to communicate with the drone pilot in real time.

Figure 44 lists the requirements for the implementation of these services that were identified by the AIRPASS, DroC^{2}om, DREAMS, IMPETUS and TERRA projects.

FIGURE 44: SERVICE REQUIREMENTS FOR THE INTERACTION WITH ATC (NON-EXHAUSTIVE)

Title	Description
Flight plan approval	A flight conformance module built in the FPM service shall be the instance responsible for approving or rejecting the individual flight plans based on defined rules and prioritization criteria.
Communication	The system shall allow the communication between ATCO/manned aviation pilots and operator/pilot through: ► R/T or ► D/L or ► general voice communication means
Datalink ATC voice performance	The C2 Link system may offer, for the relay of ATC voice services, at least the following performance: ► Voice latency: 400 ms (maximum) ► Availability: 99.998 % (minimum)
Provision of drone information to ATM system in controlled airspace	ATM systems shall receive drone positions, identification and foreseen trajectories in the proximity of airports or controlled airspace.
Alarm to supervisor	The system shall provide alarms to ATM systems in case of drone deviations near controlled airspace.
Vertical separation in VLL airspace	U-space shall ensure a common reference frame for vertical separation of drones in VLL airspace.
Sensors for Collaborative ATC Interfacing	A sensor or a set of sensors shall be available to measure the altitude.
Redundancy of communication channel for U-space information exchange	Since U-space information exchange is expected to rely on cellular networks (e.g. LTE), a redundant communication channel (e.g. satellite-based) represents a safety mitigation in areas where coverage of such networks is not ensured.
Connectivity	The selected communication infrastructure shall provide connectivity between the central system and all nodes.

E. Maturity criteria

The following tables list the SESAR maturity criteria that will be applicable to assess the maturity progress of the SESAR Solutions in the context of Digital European Sky programme, from an early stage of maturity, for example exploratory research topic, up to the transition towards deployment and implementation industrialisation, for example scope of Digital Sky Demonstrators.

These criteria will be applied by the SESAR 3 JU during the maturity gates and will also be used for maturity self-assessment performed by the project as input to the project reviews. The criteria might evolve over time to adapt to the needs of the programme. This potential evolution would be performed through the SJU Governance

E.1 Technology readiness level 1

TABLE 7: MATURITY ASSESSMENT CRITERIA FOR TRL 1

Criteria ID	Criteria definition	Where - Technical Deliverable
TRL-1.1	Has the ATM problem/challenge/need(s) that innovation would contribute to solve been identified? *- Where does the problem lie?* *- Has the ATM problem/challenge/need(s) been quantified that justify the research done? Note: an initial estimation is sufficient*	Concept Outline TRL1
TRL-1.2	Have the solutions (concepts/capabilities/methodologies) under research been defined and described?	Concept Outline TRL1
TRL-1.3	Have assumptions applicable for the innovative concept/technology been documented?	Concept Outline TRL1
TRL-1.4	Have the research hypothesis been formulated and documented? *Note: In the corresponding TRL 1 exploratory research plan (ERP), this criterion should have been already covered and it might constitute quality acceptance criteria of the TRL1 ERP itself*	exploratory research report (ERR) TRL1
TRL-1.5	Do the obtained results from the fundamental research activities suggest innovative solutions (e.g. concepts/methodologies/capabilities? *- What are these new concepts/methodologies/capabilities?* *- Can they be technically implemented?*	ERR TRL1
TRL-1.6	Have the potential strengths and benefits of the solution identified and assessed? *- Qualitative assessment on potential benefits. This will help orientate future validation activities. Optional: It may be that quantitative information already exists, in which case it should be used.*	ERR TRL1
TRL-1.7	Have the potential limitations, weaknesses and constraints of the solution under research been identified and assessed? *- The solution under research may be bound by certain constraints, such as time, geographical location, environment, cost of solutions or others.* *- Qualitative assessment on potential limitations. This will help orientate future validation activities. Optional: It may be that quantitative information already exists, in which case it may be used.*	ERR TRL1 Concept Outline TRL1
TRL-1.8	Do fundamental research results show contribution to the Programme strategic objectives e.g. performance ambitions identified at the Master Plan, SRIA and multiannual work programme (MAWP)?	ERR TRL1
TRL-1.9	Have stakeholders been identified, consulted and involved in the assessment of the results?. Has their feedback been documented in project deliverables? Have stakeholders shown their interest on the proposed solution? *Note: In the corresponding TRL 1 ERP, this criterion should have been already covered and it might constitute quality acceptance criteria of the TRL1 ERP itself*	ERR TRL1 Concept Outline TRL1
TRL-1.10	Are recommendations for further scientific research documented?	ERR TRL1 Concept Outline TRL1

E.2 Technology readiness level 2

TABLE 8: MATURITY ASSESSMENT CRITERIA FOR TRL 2

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	OPERATIONAL	OPS.TRL2.1	Is the initial documented description of the proposed ATM solution justified by the ATM Master Plan and/or SRIA e.g. reference to specific section or paragraph?	SPR-INTEROP/OSED TRL2 (i.e. mainly OSED section)
ATM Solution	OPERATIONAL	OPS.TRL2.2	Is there an initial identification and definition of the ATM SESAR Solution and related OI steps?	SPR-INTEROP/OSED TRL2 (i.e. mainly OSED section)
ATM Solution	OPERATIONAL	OPS.TRL2.3	Have different options for the new operating method been described and assessed?	SPR-INTEROP/OSED TRL2 (i.e. mainly OSED section)
ATM Solution	OPERATIONAL	OPS.TRL2.4	Have potential operating environments been identified where, if deployed, the ATM SESAR Solution could bring performance benefits?	SPR-INTEROP/OSED TRL2 (i.e. mainly OSED section)
ATM Solution	OPERATIONAL	OPS.TRL2.5	Have representative stakeholders been identified, are their needs and expectations for the ATM SESAR solution documented?	SPR-INTEROP/OSED TRL2 (i.e. mainly OSED section)
ATM Solution	SYSTEM	SYS.TRL2.1	Has the ATM solution architecture been documented? e.g. what systems may be impacted? *Note: For U-space, the references are the latest applicable version of CORUS Concept confirmed by the SJU and the U-space architecture principles*	FRD TRL2
ATM Solution	SYSTEM	SYS.TRL2.2	Have several architectural options for the ATM solution been proposed/ investigated?	FRD TRL2
ATM Solution	SYSTEM	SYS.TRL2.3	Are there needs for supporting CNS infrastructure (if any) adequately identified and justified for the different operating environments relevant for the ATM SESAR Solution?	FRD TRL2
ATM Solution	PERFORMANCE & CBA	PER.TRL2.1	Has a TRL2 Human Performance assessment been performed and documented following SESAR HP reference material?	SPR-INTEROP/OSED TRL2 (i.e. HPAR) ERR TRL2
ATM Solution	PERFORMANCE & CBA	PER.TRL2.2	Has a TRL2 performance assessment been performed and documented following SESAR performance reference material?	SPR-INTEROP/OSED TRL2 (PAR) ERR TRL2

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	PERFORMANCE & CBA	PER.TRL2.3	Does the TRL2 economic evaluation (ECO-EVAL) contain a qualitative (order of magnitude) description of the costs and benefits of the solution that allows the different impacted stakeholders to have confidence on the continuation of further research for the proposed ATM solution?	ECO-EVAL TRL2
ATM Solution	PERFORMANCE & CBA	PER.TRL2.4	Has a TRL2 Scoping and change assessment been performed and documented in a Safety Plan?	SPR-INTEROP/OSED TRL2 (i.e. SAR) ERR TRL2 (ERP TRL2)
ATM Solution	PERFORMANCE & CBA	PER.TRL2.5	Has the TRL2 preliminary security assessment been carried out in conformance with the SESAR security reference material?	SPR-INTEROP/OSED TRL2 Security Assessment Report (CONFIDENTIAL)
ATM Solution	PERFORMANCE & CBA	PER.TRL2.6	Has a TRL2 environmental assessment been performed following SESAR environmental reference material?	SPR-INTEROP/OSED TRL2 ERR TRL2 (ERP TRL2)
ATM Solution	STANDARDS & REGULATIONS	S&R.TRL2.1	Have the standardisation context been captured and an initial list of potential standardisation needs been identified?	STAND TRL2
ATM Solution	TRANSITION	TRA.TRL2.1	Are there recommendations proposed to be addressed during TRL4 related activities? E.g. additional testing conditions, open HP issues to be addressed in TRL4,... *Note 1: these recommendations should be based on an evaluation of the technical risk (Low, Medium, High), and required effort (Low, Medium, High) to advance to the next TRL level.* *Note 2: these recommendations could also be part of the Exploitation information to be produced by the project*	SPR-INTEROP/OSED TRL2 ERR TRL2
ATM Solution	VALIDATION	VAL.TRL2.1	Are the relevant R&D needs identified and documented? Have the validation objectives covered by TRL2 validation activities addressed the relevant and Key SESAR Solution R&D needs? *Note: R&D needs state major questions and open issues to be addressed during the development, verification and validation of a SESAR Solution. They justify the need to continue research on a given SESAR Solution, and the definition of validation exercises and validation objectives in following maturity phases.*	ERR TRL2

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	PROGRAMME	PRG.TRL2.1	Is there a clear identification and description of the ATM solution e.g. SESAR Solution title and definition, OI steps, etc.? *Note: the objective is to ensure the ATM solution can be included in the ATM Master Plan (e.g. ATM solution description is complete and coherent with the obtained results at all levels (solution, OI/ steps, enablers, etc.)).*	SPR-INTEROP/OSED TRL2
ATM Solution	PROGRAMME	PRG.TRL2.2	Have the operational and technical assumptions that may have impact on the integration of the ATM solution in the European ATM system been described and documented?	SPR-INTEROP/OSED TRL2
Technological Solution	OPERATIONAL	OPS.TRL2.1	Have potential operational use cases of this SESAR technological solution been identified?	FRD TRL2
Technological Solution	OPERATIONAL	OPS.TRL2.2	Have potential operating environments been identified where the SESAR Solution should be deployed?	FRD TRL2
Technological Solution	OPERATIONAL	OPS.TRL2.3	Have representative stakeholders/ users of the Technological solution been identified, are their needs and expectations for the SESAR solution documented?	ERR TRL2
Technological Solution	SYSTEM	SYS.TRL2.1	Is there a documented initial definition of the SESAR technological solution scope? (e.g. **basic architecture, major functions, interfaces**,… etc.)?	FRD TRL2
Technological Solution	SYSTEM	SYS.TRL2.2	Is this initial definition supported by results provided by **paper/analytical/ modelling/simulation** studies on the SESAR technological solution?	FRD TRL2 ERR TRL2
Technological Solution	SYSTEM	SYS.TRL2.3	Have initial functional requirements been documented?	FRD TRL2
Technological Solution	PERFORMANCE & CBA	PER.TRL2.1	Has a TRL2 Human Performance assessment been performed and documented following SESAR HP Reference Material?	FRD TRL2 ERR TRL2
Technological Solution	PERFORMANCE & CBA	PER.TRL2.2	Does the TRL2 ECO-EVAL contain a qualitative (order of magnitude) description of the costs and benefits of the solution that allows the different impacted stakeholders to have confidence on the continuation of further research for the proposed Technological solution?	ECO-EVAL TRL2
Technological Solution	PERFORMANCE & CBA	PER.TRL2.3	Has a TRL2 safety scoping & change assessment been performed and documented in a Safety Plan?	FRD TRL2 ERR TRL2

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
Technological Solution	PERFORMANCE & CBA	PER.TRL2.4	Has the TRL2 preliminary security assessment been carried out in conformance with the SESAR Security Reference Material?	FRD TRL2 Security Assessment Report (CONFIDENTIAL)
Technological Solution	PERFORMANCE & CBA	PER.TRL2.5	Has a TRL2 environmental assessment been performed following SESAR Environmental Reference Material?	FRD TRL2 ERR TRL2 (ERP TRL2)
Technological Solution	STANDARDS & REGULATIONS	S&R.TRL2.1	Have the standardisation context been captured and an initial list of potential standardisation needs been identified?	STAND TRL2
Technological Solution	TRANSITION	TRA.TRL2.1	Are there recommendations proposed to be addressed during TRL-4 related activities? *Note 1: these recommendations should be based on an evaluation of the technical risk (Low, Medium, High), and required effort (Low, Medium, High) to advance to the next TRL level.* *Note 2: these recommendations could also be part of the Exploitation information to be produced by the project*	ERR TRL2
Technological Solution	VALIDATION	VAL.TRL2.1	Have **paper/analytical/modelling/ simulation studies** of a SESAR technological solution (system enabler) mock-up been completed in **a simulated environment**?	ERR TRL2
Technological Solution	PROGRAMME	PRG.TRL2.1	Is there a clear identification and description of the Technological solution e.g. Solution title and description, relevant POI(s) and enablers (if available), etc.? *Note: the objective is to ensure the Technological solution can be later on included in the ATM Master Plan (e.g. solution description is complete and coherent with the obtained results at all levels (solution, POI, enablers, etc.)).*	FRD TRL2
Technological Solution	PROGRAMME	PRG.TRL2.2	Have the operational and technical assumptions that may have impact on the integration of the ATM solution in the European ATM system been described and documented?	FRD TRL2

E.3 Technology readiness level 4

TABLE 9: MATURITY ASSESSMENT CRITERIA FOR TRL 4

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	OPERATIONAL	OPS.TRL4.1	Is the operational concept apportioned to the SESAR Solution developed and described in the SPR-INTEROP/OSED and justified by the ATM Master Plan and/or SRIA e.g. reference to specific section or paragraph?	SPR-INTEROP/OSED TRL4
ATM Solution	OPERATIONAL	OPS.TRL4.2	Are the Operational, Performance and Safety Requirements (including information exchange requirements (IERs)) available and updated with feedback from TRL4 validation activities in the SPR-INTEROP/OSED?	SPR-INTEROP/OSED TRL4
ATM Solution	OPERATIONAL	OPS.TRL4.3	Are the Interoperability requirements (SPR-INTEROP/OSED) validated and updated after TRL4 activities?	SPR-INTEROP/OSED TRL4
ATM Solution	OPERATIONAL	OPS.TRL4.4	Is the definition of the SESAR Solution updated and refined capturing the feedback from TRL4 activities?	SPR-INTEROP/OSED TRL4
ATM Solution	OPERATIONAL	OPS.TRL4.5	Do validation results provide evidence (qualitative and quantitative) that the SESAR Solution is operationally feasible e.g. user acceptability?	VALR TRL4
ATM Solution	SYSTEM	SYS.TRL4.1	Are the required enablers identified and/or confirmed?	TS/IRS TRL4
ATM Solution	SYSTEM	SYS.TRL4.2	Has a **standalone research prototype** been successfully produced implementing the technical requirements (at the minimum the core/critical ones) in the TS/IRS?	VALR TRL4
ATM Solution	SYSTEM	SYS.TRL4.3	Are the System Requirements (TS/IRS) available and updated with feedback from TRL4 validation activities?	TS/IRS TRL4
ATM Solution	SYSTEM	SYS.TRL4.4	Are the System Requirements (TS/IRS) stable and verified? *System Requirements are traced to operational, performance and interoperability requirements captured in the SPR-INTEROP/OSED TRL4.*	TS/IRS TRL4
ATM Solution	SYSTEM	SYS.TRL4.5	Are there evidences (qualitative and quantitative) of the technical feasibility of the SESAR Solution?	VALR TRL4
ATM Solution	PERFORMANCE & CBA	PER.TRL4.1	Has a TRL4 Human Performance assessment been performed and documented following SESAR HP Reference Material?	SPR-INTEROP/OSED TRL4 VALR TRL4

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	PERFORMANCE & CBA	PER.TRL4.2	Has a TRL4 Performance Assessment on those KPAs that are applicable to the SESAR Solution been performed and documented following Performance Assessment Reference Material? *(Note that this criterion refer to any KPA different than Safety, Security, Human Performance and environmental sustainability that are covered by specific criteria)*	SPR-INTEROP/OSED (PAR) TRL4 VALR TRL4
ATM Solution	PERFORMANCE & CBA	PER.TRL4.3	Has a TRL4 Environmental Impact Assessment (EIA) been performed and documented following SESAR Environmental Reference Material?	SPR-INTEROP/OSED TRL4 VALR TRL4
ATM Solution	PERFORMANCE & CBA	PER.TRL4.4	Has the TRL4 security assessment been carried out in conformance with the SESAR Security Reference Material?	SPR-INTEROP/OSED TRL4 TS/IRS TRL4 Security Assessment Report (CONFIDENTIAL)
ATM Solution	PERFORMANCE & CBA	PER.TRL4.5	Has a TRL4 safety assessment been performed and documented as a Safety Assessment Report (Part II of the SPR-INTEROP/OSED?	SPR-INTEROP/OSED TRL4 VALR TRL4
ATM Solution	PERFORMANCE & CBA	PER.TRL4.6	Does the TRL4 CBA contain an initial quantitative assessment of the costs and benefits of the solution that allows the different impacted stakeholders to have confidence on the economic feasibility of the ATM solution?	CBA TRL4
ATM Solution	STANDARDS & **REGULATIONS**	S&R.TRL4.1	Have applicable standards and/or new standardisation needs been identified?	SPR-INTEROP/OSED TRL4 TS/IRS TRL4 STAND
ATM Solution	STANDARDS & REGULATIONS	S&R.TRL4.2	Has the solution produced material that can be used to support the initial development or update of operational and technical standards (if required)?	SPR-INTEROP/OSED TRL4 TS/IRS TRL4 STAND
ATM Solution	TRANSITION	TRA.TRL4.1	Are there any major transition issues identified e.g. institutional changes, infrastructure changes, training, etc.?	SPR-INTEROP/OSED TRL4 TS/IRS TRL4 VALR TRL4
ATM Solution	TRANSITION	TRA.TRL4.2	Are there recommendations proposed to be addressed during TRL6 related activities? E.g. additional testing conditions, open HP issues to be addressed in TRL6 *Note: these recommendations should be based on an evaluation of the technical risk (Low, Medium, High), and required effort (Low, Medium, High) to advance to the next TRL level.*	SPR-INTEROP/OSED TRL4 TS/IRS TRL4 VALR TRL4

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	VALIDATION	VAL.TRL4.1	Were the TRL4 Validation activities executed using a validation technique suitable for TRL4 objectives e.g. Real Time Simulation providing the stakeholders the requisite confidence in the results obtained?	VALR TRL4
ATM Solution	PROGRAMME	PRG.TRL4.1	Has the System Requirements (TS/IRS) traceability to SPR-INTEROP/OSED Requirements been completed after TRL4 validation activities?	TS/IRS TRL4
ATM Solution	PROGRAMME	PRG.TRL4.2	Are the relevant OI steps and enablers described and documented capturing the SESAR ATM solution scope, rationale, etc.. ? *Note: the objective is to ensure the representation of the SESAR solution (and all relevant data e.g. OI step(s), enabler(s), etc.) in the ATM Master Plan is complete and coherent with the obtained results*	SPR-INTEROP/OSED TRL4 TS/IRS TRL4
ATM Solution	PROGRAMME	PRG.TRL4.3	Have the operational and technical assumptions that may have impact on the integration of the ATM solution in the European ATM system been confirmed? (e.g. assumptions made on enablers being developed by other solutions (and used by this solution))	SPR-INTEROP/OSED TRL4 VALR TRL4
Technological Solution	OPERATIONAL	OPS.TRL4.1	Have relevant Operational Use Cases been identified and described?	TS/IRS TRL4
Technological Solution	SYSTEM	SYS.TRL4.1	Has the definition of the SESAR technological solution been refined after validation / verification activities e.g. architecture?	TS/IRS TRL4
Technological Solution	SYSTEM	SYS.TRL4.2	Have critical functions/components of the SESAR technological solution and the relevant system enablers been identified?	TS/IRS TRL4
Technological Solution	SYSTEM	SYS.TRL4.3	Has a **standalone research prototype** been successfully produced implementing the technical requirements in the TS/IRS?	TVALR TRL4
Technological Solution	SYSTEM	SYS.TRL4.4	Have **laboratory tests (based on a standalone research prototype)** shown that the SESAR technological solution (system enabler) fulfils the essential operational Use Cases?	TVALR TRL4
Technological Solution	SYSTEM	SYS.TRL4.5	Have **laboratory tests (based on a standalone research prototype)** shown (and reported) that the SESAR technological solution is technically feasible?	TVALR TRL4

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
Technological Solution	SYSTEM	SYS.TRL4.6	Have **laboratory tests (based on a standalone research prototype)** verified that the integration of the SESAR technological solution (system enabler) **with other related system enablers is technically feasible**?	TVALR TRL4
Technological Solution	SYSTEM	SYS.TRL4.7	Have functional requirements been refined and performance requirements (e.g. quality of service requirements) been documented in the TS/IRS?	TS/IRS TRL4
Technological Solution	SYSTEM	SYS.TRL4.8	Are laboratory to engineering scale-up issues understood and resolved?	TS/IRS TRL4 TVALR TRL4
Technological Solution	PERFORMANCE & CBA	PER.TRL4.1	Has a TRL4 Human Performance assessment been performed and documented following SESAR HP Reference Material?	TS/IRS TRL4
Technological Solution	PERFORMANCE & CBA	PER.TRL4.2	Have potential interactions with related SESAR (ATM or technological) Solutions been considered? What are the solution relationship and relative contribution to performance (e.g. weight per KPA) with the other solutions once the solutions may be deployed?	TVALR TRL4
Technological Solution	PERFORMANCE & CBA	PER.TRL4.3	Does the TRL4 CBA contain an initial quantitative assessment of the costs and benefits of the solution that allows the different impacted stakeholders to have confidence on the economic feasibility of the Technological solution?	CBA TRL4
Technological Solution	PERFORMANCE & CBA	PER.TRL4.4	Have laboratory tests shown that the SESAR technological solution (system enabler) prototype meets the critical functional and performance requirements?	TVALR TRL4
Technological Solution	PERFORMANCE & CBA	PER.TRL4.5	Has the TRL4 security assessment been carried out in conformance with the SESAR Security Reference Material?	TS/IRS TRL4 Security Assessment Report (CONFIDENTIAL)
Technological Solution	PERFORMANCE & CBA	PER.TRL4.6	Has a TRL4 safety assessment been performed and documented as a Safety Assessment Report (in TS/IRS TRL4?	TS/IRS TRL4
Technological Solution	PERFORMANCE & CBA	PER.TRL4.7	Has a TRL4 Environmental Impact Assessment (EIA) been performed and documented following SESAR Environmental Reference Material?	TS/IRS TRL4 TVALR TRL4
Technological Solution	STANDARDS & REGULATIONS	S&R.TRL4.1	Have applicable standards and/or new standardisation needs been identified?	TS/IRS TRL4 STAND
Technological Solution	STANDARDS & REGULATIONS	S&R.TRL4.2	Has the solution produced material that can be used to support the initial development or update of operational and technical standards (if required)?	TS/IRS TRL4 STAND

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
Technological Solution	TRANSITION	TRA.TRL4.1	Are there any major transition issues identified e.g. institutional changes, infrastructure changes, training, etc.?	TS/IRS TRL4 TVALR TRL4
Technological Solution	TRANSITION	TRA.TRL4.2	Are there recommendations proposed to be addressed during TRL-6 related activities? *Note: these recommendations should be based on an evaluation of the technical risk (Low, Medium, High), and required effort (Low, Medium, High) to advance to the next TRL level.*	TS/IRS TRL4 TVALR TRL4
Technological Solution	VALIDATION	VAL.TRL4.1	Has laboratory-scale testing of a SESAR technological solution (system enabler) prototype been completed in **a simulated environment**?	TVALR TRL4
Technological Solution	PROGRAMME	PRG.TRL4.1	Have representative stakeholders contributed to identify functional and performance requirements for the SESAR technological solution?	TS/IRS TRL4
Technological Solution	PROGRAMME	PRG.TRL4.2	Are the relevant system enablers described and documented, capturing the SESAR technological solution definition, rationale, etc.. ? *Note: the objective is to ensure the representation of the SESAR solution (and all relevant data e.g. POI step(s), enabler(s), etc.) in the ATM Master Plan is complete and coherent with the obtained results*	TS/IRS TRL4
Technological Solution	PROGRAMME	PRG.TRL4.3	Have the operational and technical assumptions that may have impact on the integration of the Technological solution in the European ATM system been confirmed? (e.g. assumptions made on enablers being developed by other solutions (and used by this solution))	TS/IRS TRL4

E.4 Technology readiness level 6

TABLE 10: **MATURITY ASSESSMENT CRITERIA FOR TRL 6**

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	OPERATIONAL	OPS.TRL6.1	Is the operational concept apportioned to the SESAR Solution refined and further detailed and documented after TRL6 activities in the SPR-INTEROP/ OSED and justified by the ATM Master Plan and/or SRIA e.g. reference to specific section or paragraph?	SPR-INTEROP/OSED TRL6
ATM Solution	OPERATIONAL	OPS.TRL6.2	Are the OI steps under the scope of the SESAR Solution fully described and documented e.g. definition, description and rationale are updated based on the feedback from validation results, etc...?	SPR-INTEROP/OSED TRL6
ATM Solution	OPERATIONAL	OPS.TRL6.3	Are the Operational, Performance and Safety Requirements (including information exchange requirements (IERs)) available and updated with feedback from TRL6 validation activities in the SPR-INTEROP/OSED?	SPR-INTEROP/OSED TRL6
ATM Solution	OPERATIONAL	OPS.TRL6.4	Are the Interoperability requirements (SPR-INTEROP/OSED) updated after TRL6 activities?	SPR-INTEROP/OSED TRL6
ATM Solution	OPERATIONAL	OPS.TRL6.5	Have the most critical dependent SESAR Solutions been integrated and validated together, and shown that they work coherently?	VALR TRL6
ATM Solution	OPERATIONAL	OPS.TRL6.6	Do validation results confirm the evidences (quantitative and qualitative) on the operational feasibility and acceptability of the SESAR Solution obtained in previous TRL?	VALR TRL6
ATM Solution	SYSTEM	SYS.TRL6.1	Are the enablers under the scope of the SESAR Solution fully described and documented e.g. description and rationale are updated based on the feedback from validation results, etc...?	TS/IRS TRL6
ATM Solution	SYSTEM	SYS.TRL6.2	Has a **"high fidelity" prototype** of the system supporting the ATM SESAR solution been produced and integrated on an Industrial Based Platform (close to operational environment)? ***High Fidelity prototype:*** *all/significant number of technical requirements in the TS/IRS have been successfully implemented in the prototype.*	VALR TRL6

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	SYSTEM	SYS.TRL6.3	Are the System Requirements (TS/IRS) validated, stable and updated after TRL6 activities?	TS/IRS TRL6
ATM Solution	SYSTEM	SYS.TRL6.4	Are the CNS infrastructure requirements identified and defined?	TS/IRS TRL6
ATM Solution	SYSTEM	SYS.TRL6.5	Are the SWIM infrastructure requirements identified and defined?	TS/IRS TRL6
ATM Solution	SYSTEM	SYS.TRL6.6	Are the evidences (quantitative and qualitative) on the technical feasibility of the SESAR Solution obtained in previous TRL confirmed?	VALR TRL6
ATM Solution	PERFORMANCE & CBA	PER.TRL6.1	Has a TRL6 Human Performance assessment been performed and documented following SESAR HP Reference Material?	SPR-INTEROP/OSED TRL6 VALR TRL6
ATM Solution	PERFORMANCE & CBA	PER.TRL6.2	Has a TRL6 Performance Assessment on those KPAs that are applicable to the SESAR Solution been performed and documented following SESAR Performance Assessment Reference Material (e.g. SESAR Performance Framework)? *(Note that this criterion refer to any KPA different than Safety, Security, Human Performance and environmental sustainability that are covered by specific criteria)*	SPR-INTEROP/OSED (PAR) TRL6 VALR TRL6
ATM Solution	PERFORMANCE & CBA	PER.TRL6.3	Has a TRL6 Environmental Impact Assessment (EIA) been performed and documented following SESAR Environmental Reference Material?	SPR-INTEROP/OSED TRL6 VALR TRL6
ATM Solution	PERFORMANCE & CBA	PER.TRL6.4	Has a TRL6 safety assessment been performed and documented as a Safety Assessment Report?	SPR-INTEROP/OSED TRL6 TS/IRS TRL6 VALR TRL6
ATM Solution	PERFORMANCE & CBA	PER.TRL6.5	Has the TRL6 security assessment been carried out in conformance with the SESAR Security Reference Material?	SPR-INTEROP/OSED TRL6 TS/IRS TRL6 Security Assessment Report (CONFIDENTIAL)
ATM Solution	PERFORMANCE & CBA	PER.TRL6.6	Does the TRL6 CBA contain a quantitative assessment of the costs and benefits of the solution that allows the different impacted stakeholders to have confidence on the ATM solution industrialisation and deployment?	CBA TRL6

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	STANDARDS & **REGULATIONS**	S&R.TRL6.1	Is the material produced and documented in the solution technical deliverables sufficiently developed and mature to contribute to the mature drafting (development or update) of all necessary standards?	SPR-INTEROP/OSED TRL6 TS/IRS TRL6 STAND
ATM Solution	STANDARDS & REGULATIONS	S&R.TRL6.2	Have the regulatory needs been identified?	SPR-INTEROP/OSED TRL6 TS/IRS TRL6 REG
ATM Solution	TRANSITION	TRA.TRL6.1	Are the major transition issues analysed and mitigation measures proposed taking into account evolution of the SESAR Solution, relevant OI steps and supporting enablers?	VALR TRL6
ATM Solution	TRANSITION	TRA.TRL6.2	Are there recommendations proposed to be addressed during industrialisation and deployment? *E.g. any open HP issues / recommendation for industrialisation & deployment have been identified and documented* *Note: these recommendations should be based on an evaluation of the technical risk (Low, Medium, High), and required effort (Low, Medium, High) to advance to the next TRL level.*	VALR TRL6
ATM Solution	VALIDATION	VAL.TRL6.1	Were the TRL6 Validation activities executed using a validation technique suitable for that maturity level e.g. shadow mode and / or live trials? *Note: the validation techniques mentioned above are just examples of those that are normally applied during TRL6 level. However, there are others that could be also applied if dully justified e.g. FTS could be valuable for supporting performance assessment and potential extrapolation at ECAC level.*	VALR TRL6
ATM Solution	PROGRAMME	PRG.TRL6.1	Has the System Requirements (TS/IRS) traceability to SPR-INTEROP/OSED Requirements been completed and updated after V3 validation activities?	TS/IRS TRL6
ATM Solution	PROGRAMME	PRG.TRL6.2	Are the relevant OI steps and enablers updated capturing the SESAR ATM solution definition, description, rationale, etc.. ? *Note: the objective is to ensure the representation of the SESAR solution (and all relevant data e.g. OI step(s), enabler(s), etc.) in the ATM Master Plan is complete and coherent with the obtained results and it is sufficient to secure transition towards industrialisation and deployment). In particular a clear and complete description/definition of a list of proposed implementation objectives.*	SPR-INTEROP/OSED TRL6 TS/IRS TRL6 Contextual Note TRL6

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	PROGRAMME	PRG.TRL6.3	Have the operational and technical assumptions that may have impact on the integration of the ATM solution in the European ATM system been confirmed? (e.g. assumptions made on enablers being developed by other solutions (and used by this solution))	SPR-INTEROP/OSED TRL6 VALR TRL6
Technological Solution	OPERATIONAL	OPS.TRL6.1	Have relevant Operational Use Cases been that could be supported by the SESAR technological solution been refined after technical validation activities took place?	TS/IRS TRL6
Technological Solution	SYSTEM	SYS.TRL6.1	Has the description / definition of the SESAR technological solution been refined, consolidated and agreed in a TS/IRS after validation / verification activities e.g. final architecture?	TS/IRS TRL6
Technological Solution	SYSTEM	SYS.TRL6.2	Has a **"high fidelity" prototype** of the SESAR technological solution (system enabler) been produced and integrated on an Industrial Based Platform (close to operational environment)? ***High Fidelity prototype:*** *all/significant number of technical requirements in the TS/IRS have been successfully implemented in the prototype.*	TVALR TRL6
Technological Solution	SYSTEM	SYS.TRL6.3	Has the technical feasibility of the SESAR technological solution been confirmed thanks to **technical validation activities (based on a "high fidelity" prototype integrated on an IBP) performed in a target operational environment?**	TVALR TRL6
Technological Solution	SYSTEM	SYS.TRL6.4	Have **technical validation activities (based on a "high fidelity" prototype integrated on an IBP) performed in a target operational environment** shown that the SESAR technological solution fulfils the most significant operational Use Cases?	TVALR TRL6
Technological Solution	SYSTEM	SYS.TRL6.5	Have **technical validation activities (based on a "high fidelity" prototype integrated on an IBP) performed in a target operational environment** shown that the SESAR technological solution can be integrated within the European ATM system?	TVALR TRL6
Technological Solution	SYSTEM	SYS.TRL6.6	Have final functional and performance requirements been documented in the TS/IRS? Are technical specifications complete and documented?	TS/IRS TRL6

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
Technological Solution	PERFORMANCE & CBA	PER.TRL6.1	Has a TRL6 Human Performance assessment been performed and documented following SESAR HP Reference Material?	TS/IRS TRL6
Technological Solution	PERFORMANCE & CBA	PER.TRL6.2	Have potential interactions with related SESAR (ATM or technological) Solutions been considered? What are the solution relationship and relative contribution to performance (e.g. weight per KPA) with the other solutions once the solutions will be deployed?	TVALR TRL6
Technological Solution	PERFORMANCE & CBA	PER.TRL6.3	Does the TRL6 CBA contain a quantitative assessment of the costs and benefits of the solution that allows the different impacted stakeholders to have confidence on the Technological solution industrialisation and deployment?	CBA TRL6
Technological Solution	PERFORMANCE & CBA	PER.TRL6.4	Have technical validation activities been performed on an environment close to the target operational one confirmed that the SESAR technological solution meets the critical functional and performance requirements in the TS/IRS?	TVALR TRL6
Technological Solution	PERFORMANCE & CBA	PER.TRL6.5	Has the TRL6 security assessment been carried out in conformance with the SESAR Security Reference Material?	TS/IRS TRL6 Security Assessment Report (CONFIDENTIAL)
Technological Solution	PERFORMANCE & CBA	PER.TRL6.6	Has a TRL6 safety assessment been performed and documented as a Safety Assessment Report?	TS/IRS TRL6
Technological Solution	PERFORMANCE & CBA	PER.TRL6.7	Has a TRL6 Environmental Impact Assessment (EIA) been performed and documented following SESAR Environmental Reference Material?	TS/IRS TRL6 TVALR TRL6
Technological Solution	STANDARDS & REGULATIONS	S&R.TRL6.1	Is the material produced and documented in the solution technical deliverables sufficiently developed and mature to contribute to the mature drafting (development or update) of all necessary standards?	TS/IRS TRL6 STAND
Technological Solution	STANDARDS & REGULATIONS	S&R.TRL6.2	Have the regulatory needs been identified?	TS/IRS TRL6 REG
Technological Solution	TRANSITION	TRA.TRL6.1	Are the major transition issues analysed and mitigation measures proposed taking into account evolution of the SESAR Solution and supporting enablers?	TVALR TRL6

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
Technological Solution	TRANSITION	TRA.TRL6.2	Are there recommendations proposed to be addressed during industrialisation and deployment? *E.g. any open safety, security, performance,... issues / recommendation for industrialisation & deployment have been identified and documented* *Note: these recommendations should be based on an evaluation of the technical risk (Low, Medium, High), and required effort (Low, Medium, High) to advance to the next TRL level.*	TVALR TRL6
Technological Solution	VALIDATION	VAL.TRL6.1	Were the TRL6 technical Validation activities executed using a technique suitable for that maturity level e.g. testing of a SESAR technological solution prototype integrated on an IBP representative of the **target operational environment**?	TVALR TRL6
Technological Solution	PROGRAMME	PRG.TRL6.1	Have representative stakeholders/ users contributed to the refinement of functional and performance requirements for the SESAR technological solution?	TS/IRS TRL6
Technological Solution	PROGRAMME	PRG.TRL6.2	Are the relevant system enablers updated capturing the SESAR technological solution definition, rationale, etc.. ? *Note: the objective is to ensure the representation of the SESAR solution (and all relevant data e.g. POI step(s), enabler(s), etc.) in the ATM Master Plan is complete and coherent with the obtained results and it is sufficient to secure transition towards industrialisation and deployment). In particular a clear and complete description/definition of a list of proposed implementation objectives.*	TS/IRS TRL6 Contextual Note TRL6
Technological Solution	PROGRAMME	PRG.TRL6.3	Have the operational and technical assumptions that may have impact on the integration of the Technological solution in the European ATM system been confirmed? (e.g. assumptions made on enablers being developed by other solutions (and used by this solution))	TS/IRS TRL6

E.5 Technology readiness level 7

TABLE 11: **MATURITY ASSESSMENT CRITERIA FOR TRL 7**

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	OPERATIONAL	OPS.TRL7.1	Does the SPR-INTEROP/OSED provide a clear description of the new operating method introduced by the proposed SESAR Solution(s)?	SPR-INTEROP/ OSED TRL7
ATM Solution	OPERATIONAL	OPS.TRL7.2	Are the OI steps under the scope of the SESAR Solution fully described, defined and documented e.g. description and rationale are updated based on the feedback from validation results, etc…?	SPR-INTEROP/ OSED TRL7
ATM Solution	OPERATIONAL	OPS.TRL7.3	Are the Operational, Performance and Safety Requirements (including information exchange requirements (IERs)) and Interoperability requirements available and updated with feedback from TRL7 validation activities in the SPR-INTEROP/OSED?	SPR-INTEROP/ OSED TRL7
ATM Solution	OPERATIONAL	OPS.TRL7.4	Do validation results provide evidences (quantitative and qualitative) of the operational feasibility and acceptability of the proposed SESAR Solution?	VALR TRL7
ATM Solution	SYSTEM	SYS.TRL7.1	Has an **"industrialised system prototype"** of the SESAR solution been produced, integrated and tested in a representative environment of the target operational environment? ***Industrialised system prototype**: Early versions of end-user systems, to confirm deployment readiness of the targeted solution at a larger scale.*	VALR TRL7
ATM Solution	SYSTEM	SYS.TRL7.2	Have all interfaces been tested individually under stressed and anomalous conditions?	VALR TRL7
ATM Solution	SYSTEM	SYS.TRL7.3	Have validation activities been performed in a target operational environment e.g. **demonstration in actual or simulated operational environment** verified the **technical feasibility** of the SESAR solution?	VALR TRL7
ATM Solution	SYSTEM	SYS.TRL7.4	Have validation activities been performed in a target operational environment e.g. **demonstration in actual or simulated operational environment** shown that the SESAR solution fulfils the most relevant operational Use Cases?	VALR TRL7
ATM Solution	SYSTEM	SYS.TRL7.5	Have validation activities been performed in a target operational environment e.g. **demonstration in actual or simulated operational environment** verified that the integration of the SESAR solution **in the European ATM system is technically feasible**?	VALR TRL7

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	SYSTEM	SYS.TRL7.6	Have final functional and performance requirements (e.g. quality of service requirements) been documented in the TS/IRS? Are technical specifications complete and documented?	TS/IRS TRL7
ATM Solution	SYSTEM	SYS.TRL7.7	Have demonstrations been performed on the target operational environment **e.g. demonstration in actual or simulated operational environment** confirmed that an "actual system prototype" of the SESAR solution meets the critical functional and non-functional requirements in the TS/IRS?	VALR TRL7
ATM Solution	PERFORMANCE & CBA	PER.TRL7.1	Has a TRL7 Human Performance assessment been performed and documented following SESAR HP Reference Material? Note: if a TRL6 Human Performance assessment has been performed in the past, this criterion refers to the confirmation or update of such HP assessment considering the latest design options retained for the fast-track.	SPR-INTEROP/ OSED TRL7
ATM Solution	PERFORMANCE & CBA	PER.TRL7.2	Has a TRL7 Performance Assessment on those KPAs that are applicable to the SESAR Solution been performed, in accordance with SESAR Performance Framework metrics, extrapolated to ECAC level following SESAR guidance?	SPR-INTEROP/ OSED TRL7 VALR TRL7
ATM Solution	PERFORMANCE & CBA	PER.TRL7.3	Does the TRL7 CBA contain a quantitative assessment of the costs and benefits of the solution that allows the different impacted stakeholders to have confidence on the ATM solution industrialisation and deployment?	CBA TRL7
ATM Solution	PERFORMANCE & CBA	PER.TRL7.4	Has a TRL7 Environmental Impact Assessment (EIA) been performed and documented following SESAR Environmental Reference Material? Note: if a TRL6 Environmental Impact Assessment (EIA) has been performed in the past, this criterion refers to the confirmation or update of such Environmental Impact Assessment (EIA) considering the latest design options retained for the fast-track.	SPR-INTEROP/ OSED TRL7 VALR TRL7
ATM Solution	PERFORMANCE & CBA	PER.TRL7.5	Has the TRL7 security assessment been carried out in conformance with the SESAR Security Reference Material? Note: if a TRL6 security assessment has been performed in the past, this criterion refers to the confirmation or update of such security assessment considering the latest design options retained for the fast-track.	SPR-INTEROP/ OSED TRL7 TS/IRS TRL7 Security Assessment Report (CONFIDENTIAL)

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	PERFORMANCE & CBA	PER.TRL7.6	Has a TRL7 safety assessment been performed and documented as a Safety Assessment Report?	SPR-INTEROP/ OSED TRL7 TS/IRS TRL7 VALR TRL7
ATM Solution	STANDARDS & REGULATIONS	S&R.TRL7.1	Has any necessary standard significantly progressed (ready for final approval) thanks to the Solution input material?	SPR-INTEROP/ OSED TRL7 TS/IRS TRL7 STAND
ATM Solution	STANDARDS & REGULATIONS	S&R.TRL7.2	Has the project contribution to applicable regulations been documented?	SPR-INTEROP/ OSED TRL7 TS/IRS TRL7 REG
ATM Solution	STANDARDS & REGULATIONS	S&R.TRL7.3	Which means of compliance (MOC) been used/tailored to show compliance with the applicable regulations?	SPR-INTEROP/ OSED TRL7 TS/IRS TRL7 REG
ATM Solution	STANDARDS & REGULATIONS	S&R.TRL7.4	Has a Certification Review Item (CRI) for the airworthiness aspect been hold?	SPR-INTEROP/ OSED TRL7 TS/IRS TRL7 REG
ATM Solution	TRANSITION	TRA.TRL7.1	Are there recommendations proposed to be addressed during higher TRL? *Note: these recommendations should be based on an evaluation of the technical risk (Low, Medium, High), and required effort (Low, Medium, High) to advance to the next TRL level.*	VALR TRL7
ATM Solution	VALIDATION	VAL.TRL7.1	Were the TRL7 technical Validation activities executed using a technique suitable for that maturity level e.g. live trials and in an operational environment representative of the target one? *Note: The VALP TRL7 should include an explanation of how the selected testing environment is relevant to the expected target operational environment where the SESAR solution may be deployed. Also, justification of why the selected validation technique is appropriate to complete TRL7 (live trials may not be the only technique appropriate to demonstrate TRL7).*	VALR TRL7
ATM Solution	VALIDATION	VAL.TRL7.2	Was the system at or near scale of the operational system, with most functions available for test	VALR TRL7

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
ATM Solution	PROGRAMME	PRG.TRL7.1	Are the solution and relevant OI steps and enablers updated capturing the SESAR solution definition, rationale, etc.. ? *Note: the objective is to ensure the representation of the SESAR solution (and all relevant data e.g. OI step(s), enabler(s), etc.) in the ATM Master Plan is complete and coherent with the obtained results and it is sufficient to secure transition towards industrialisation and deployment). In particular a clear and complete description/definition of a list of proposed implementation objectives.*	SPR-INTEROP/ OSED TRL7 TS/IRS TRL7 Contextual Note TRL7
Technological Solution	OPERATIONAL	OPS.TRL7.1	Have relevant Operational Use Cases been that could be supported by the SESAR technological solution been refined after technical validation activities took place?	TS/IRS TRL7
Technological Solution	SYSTEM	SYS.TRL7.1	Has an **"industrialised system prototype"** of the SESAR solution been produced, integrated and tested in a representative environment of the target operational environment? ***Industrialised system prototype**: Early versions of end-user systems, to confirm deployment readiness of the targeted solution at a larger scale.*	TVALR TRL7
Technological Solution	SYSTEM	SYS.TRL7.2	Have all interfaces been tested individually under stressed and anomalous conditions?	TVALR TRL7
Technological Solution	SYSTEM	SYS.TRL7.3	Have validation activities been performed in a target operational environment e.g. **demonstration in actual or simulated operational environment** verified the **technical feasibility** of the SESAR solution?	TVALR TRL7
Technological Solution	SYSTEM	SYS.TRL7.4	Have validation activities been performed in a target operational environment e.g. **demonstration in actual or simulated operational environment** shown that the SESAR solution fulfils the most relevant operational Use Cases?	TVALR TRL7
Technological Solution	SYSTEM	SYS.TRL7.5	Have validation activities been performed in a target operational environment e.g. **demonstration in actual or simulated operational environment** verified that the integration of the SESAR solution **in the European ATM system is technically feasible**?	TVALR TRL7
Technological Solution	SYSTEM	SYS.TRL7.6	Have final functional and performance requirements (e.g. quality of service requirements) been documented in the TS/ IRS? Are technical specifications complete and documented?	TS/IRS TRL7

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
Technological Solution	SYSTEM	SYS.TRL7.7	Have demonstrations been performed on the target operational environment **e.g. demonstration in actual or simulated operational environment** confirmed that an "actual system prototype" of the SESAR solution meets the critical functional and non-functional requirements in the TS/IRS?	TVALR TRL7
Technological Solution	PERFORMANCE & CBA	PER.TRL7.1	Has a TRL7 Human Performance assessment been performed and documented following SESAR HP Reference Material? Note: if a TRL6 Human Performance assessment has been performed in the past, this criterion refers to the confirmation or update of such HP assessment considering the latest design options retained for the fast-track.	TS/IRS TRL7
Technological Solution	PERFORMANCE & CBA	PER.TRL7.2	Have potential interactions with related SESAR (ATM or technological) Solutions been considered? What are the solution relationship and relative contribution to performance (e.g. weight per KPA) with the other solutions once the solutions will be deployed?	TS/IRS TRL7 VALR TRL7
Technological Solution	PERFORMANCE & CBA	PER.TRL7.3	Does the TRL7 CBA contain a quantitative assessment of the costs and benefits of the solution that allows the different impacted stakeholders to have confidence on the Technological solution industrialisation and deployment?	CBA TRL7
Technological Solution	PERFORMANCE & CBA	PER.TRL7.4	Has a TRL7 Environmental Impact Assessment (EIA) been performed and documented following SESAR Environmental Reference Material? Note: if a TRL6 Environmental Impact Assessment (EIA) has been performed in the past, this criterion refers to the confirmation or update of such Environmental Impact Assessment (EIA) considering the latest design options retained for the fast-track.	TS/IRS TRL7 VALR TRL7
Technological Solution	PERFORMANCE & CBA	PER.TRL7.5	Has the TRL7 security assessment been carried out in conformance with the SESAR Security Reference Material? Note: if a TRL6 security assessment has been performed in the past, this criterion refers to the confirmation or update of such security assessment considering the latest design options retained for the fast-track.	TS/IRS TRL7 Security Assessment Report (CONFIDENTIAL)
Technological Solution	PERFORMANCE & CBA	PER.TRL7.6	Has a TRL7 safety assessment been performed and documented as a Safety Assessment Report?	TS/IRS TRL7 VALR TRL7

Type of SESAR Solution	Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
Technological Solution	STANDARDS & REGULATIONS	S&R.TRL7.1	Has any necessary standard significantly progressed (ready for final approval) thanks to the Solution input material?	TS/IRS TRL7 STAND
Technological Solution	STANDARDS & **REGULATIONS**	S&R.TRL7.2	Has the project contribution to applicable regulations been documented?	TS/IRS TRL7 REG
Technological Solution	STANDARDS & REGULATIONS	S&R.TRL7.3	Which means of compliance (MOC) been used/tailored to show compliance with the applicable regulations?	TS/IRS TRL7 REG
Technological Solution	STANDARDS & REGULATIONS	S&R.TRL7.4	Has a Certification Review Item (CRI) for the airworthiness aspect been hold?	TS/IRS TRL7 REG
Technological Solution	TRANSITION	TRA.TRL7.1	Are there recommendations proposed to be addressed during higher TRL? *Note: these recommendations should be based on an evaluation of the technical risk (Low, Medium, High), and required effort (Low, Medium, High) to advance to the next TRL level.*	TVALR TRL7
Technological Solution	VALIDATION	VAL.TRL7.1	Were the TRL7 technical Validation activities executed using a technique suitable for that maturity level e.g. live trials and in an operational environment representative of the target one? *Note: The TVALP TRL7 should include an explanation of how the selected testing environment is relevant to the expected target operational environment where the SESAR solution may be deployed. Also, justification of why the selected validation technique is appropriate to complete TRL7 (live trials may not be the only technique appropriate to demonstrate TRL7).*	TVALR TRL7
Technological Solution	VALIDATION	VAL.TRL7.2	Was the system at or near scale of the operational system, with most functions available for test?	TVALR TRL7
Technological Solution	PROGRAMME	PRG.TRL7.1	Are the solution and relevant POI steps and enablers updated capturing the SESAR solution definition, rationale, etc.. ? *Note: the objective is to ensure the representation of the SESAR solution (and all relevant data e.g. POI step(s), enabler(s), etc.) in the ATM Master Plan is complete and coherent with the obtained results and it is sufficient to secure transition towards industrialisation and deployment). In particular a clear and complete description/definition of a list of proposed implementation objectives.*	TS/IRS TRL7 Contextual Note TRL7

E.6 Technology readiness level 8

TABLE 12: MATURITY ASSESSMENT CRITERIA FOR TRL 8

Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
OPERATIONAL	OPS.TRL8.1	Does the DEMOR provide a clear description of the new operating method introduced by the SESAR Solution(s) under the scope of the DSD?	DEMOR
OPERATIONAL	OPS.TRL8.2	Does the Demonstration Report provide the list of operational, safety, performance and interoperability requirements that characterise the SESAR Solution(s) under the scope of the DSD? *Note:* ▪ *If the SESAR solutions under scope have been previously validated in SESAR, the DSDs activities shall build on top of the relevant SESAR Solution(s) data packs delivered in SESAR 1 or SESAR 2020. The DSDs results shall contribute to update (if required) the relevant SESAR solution datapack content (e.g. operational requirements, safety and performance requirements, interoperability, etc.;* ▪ *For those SESAR solutions validated outside SESAR, the DSDs shall propose a solution title and description and also document the minimum set of operational requirements, safety and performance requirements, interoperability, etc required to complete standardisation and regulatory activities in preparation for deployment.*	DEMOR
OPERATIONAL	OPS.TRL8.3	Have the demonstration exercises been performed in a (sub)operating environment that is representative of the one intended for the SESAR Solution(s) under the scope of the Demonstration?	DEMOR
OPERATIONAL	OPS.TRL8.4	Has the project demonstrated that the integration of the SESAR solution(s) in an "actual operational environment" is operationally feasible?	DEMOR
SYSTEM	SYS.TRL8.1	Does the Demonstration Report provide the list of technical requirements that characterise the SESAR Solution(s) under the scope of the DSD? *Note:* ▪ *If the SESAR solutions under scope have been previously validated in SESAR, the DSDs activities shall build on top of the relevant SESAR Solution(s) data packs delivered in SESAR 1 or SESAR 2020. The DSDs results shall contribute to update (if required) the relevant SESAR solution datapack content (e.g. technical requirements, etc.);* ▪ *For those SESAR solutions validated outside SESAR, the DSDs shall propose a solution title and description and also document the minimum set of technical requirements, etc. required to complete standardisation and regulatory activities in preparation for deployment.*	DEMOR
SYSTEM	SYS.TRL8.2	Has the "actual system" of the SESAR solution(s) been produced and integrated in the target operational environment? *Actual system: represents a production unit (i.e. the actual subsystem or system) successfully manufactured and integrated in the target operational environment.*	DEMOR

Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
SYSTEM	SYS.TRL8.3	Has an "actual system" demonstrated that it meets critical functional and performance requirements in the intended target operating environment?	DEMOR
SYSTEM	SYS.TRL8.4	Has a scalability analysis to handle large scale realistic use-cases been performed and reported in the DEMO Report?	DEMOR
SYSTEM	SYS.TRL8.5	Has the project demonstrated that the integration of the "actual system(s)" of the SESAR solution(s) in the target operational environment is technically feasible?	DEMOR
PERFORMANCE & CBA	PER.TRL8.1	Have the performance assessments been performed and documented following SESAR Performance Assessment Reference Material? Note: this criterion refers to any other KPA beyond HP, safety, security and environmental sustainability that are covered by specific criteria.	DEMOR
PERFORMANCE & CBA	PER.TRL8.2	Has a safety assessment been performed and documented?	DEMOR
PERFORMANCE & CBA	PER.TRL8.3	Has the security assessment (including cybersecurity relevant aspects) been carried out and documented in conformance with the SESAR Security Reference Material? Note: if a TRL6/7 security assessment has been performed in the past, this criterion refers to the confirmation or update of such security assessment considering the latest design options retained for the demonstration.	DEMOR
PERFORMANCE & CBA	PER.TRL8.4	Has the Human Performance assessment been carried out and documented in conformance with the SESAR Human Performance Reference Material? Note: if a TRL6/7 Human Performance assessment has been performed in the past, this criterion refers to the confirmation or update of such HP assessment considering the latest design options retained for the demonstration.	DEMOR
PERFORMANCE & CBA	PER.TRL8.5	Have training needs been specified in sufficient detail?	DEMOR
PERFORMANCE & CBA	PER.TRL8.6	Have changes in competence requirements and the impact on recruitment and selection been considered?	DEMOR
PERFORMANCE & CBA	PER.TRL8.7	Has a Environmental Impact Assessment (EIA) been performed and documented following SESAR Environmental Reference Material?	DEMOR
STANDARDS & REGULATIONS	S&R.TRL8.1	Are the required operational or technical standards available for deploying the SESAR solution(s) under the scope of the DSD?	STAND
STANDARDS & REGULATIONS	S&R.TRL8.2	Are the required regulatory material ready for deploying the SESAR solution(s) under the scope of the DSD?	REG
STANDARDS & REGULATIONS	S&R.TRL8.3	Which means of compliance (MOC) been used/tailored to show compliance with the applicable regulations?	REG

Thread	Criteria ID	Criteria definition	Where - Technical Deliverable
STANDARDS & REGULATIONS	S&R.TRL8.4	Has a Certification Review Item (CRI) for the airworthiness aspect been hold?	REG
TRANSITION	TRA.TRL8.1	Are there recommendations proposed to be addressed during large-scale deployment? *Note: these recommendations should be based on an evaluation of the technical risk (Low, Medium, High), and required effort (Low, Medium, High) towards large scale deployment.*	DEMOR
DEMONSTRATION	DEMO.TRL8.1	Have the demonstration exercises been performed in operating environments that are representative of the ones intended for the deployment of the SESAR Solution(s) under the scope of the Demonstration?	DEMOR
DEMONSTRATION	DEMO.TRL8.2	Did the demonstration activities covered at least 20% of the target operational environments where SESAR solution(s) should be deployed?	DEMOR
DEMONSTRATION	DEMO.TRL8.3	Was the system completed and fully integrated with relevant operational systems (people, processes, hardware and software), most user documentation, training documentation, and maintenance documentation completed and with authorisation by EASA and corresponding NSA?	DEMOR
PROGRAMME	PRG.TRL8.1	Are the solution and relevant OI/POI steps and enablers updated capturing the SESAR solution definition, rationale, etc.. ? Note: the objective is to ensure the representation of the SESAR solution (and all relevant data e.g. OI/POI step(s), enabler(s), etc.) in the ATM Master Plan is complete and coherent with the obtained results and it is sufficient to secure transition towards deployment). In particular a clear and complete description/definition of a list of proposed implementation objectives.	DEMOR Contextual Note TRL8

F. Multiannual budget (operational expenditure)

Table 13 outlines the 2021–2031 budget for operational expenditure, per type of activity, in commitments and payments.

TABLE 13: BREAKDOWN OF 2021–2031 BUDGET FOR OPERATIONAL EXPENDITURE, PER TYPE OF ACTIVITY, IN COMMITMENTS AND PAYMENTS

COMMITMENT APPROPRIATIONS													
Reference	Total amount	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
ER 1	23,725,000		23,725,000										23,725,000
ER 2	23,725,000			12,205,066	11,519,934								23,725,000
ER 3	23,725,000					23,725,000							23,725,000
ER 4	23,725,000							23,725,000					23,725,000
IR 1	171,000,000		100,337,066	70,662,934									171,000,000
IR 2	171,000,000					120,000,000	51,000,000						171,000,000
IR 3	85,000,000							85,000,000					85,000,000
Programme support	32,000,000			4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000		32,000,000
Experts call evaluations	2,450,000		700,000	350,000		700,000		700,000					2,450,000
Experts for deliverables and project reviews	2,800,000			350,000	350,000	350,000	350,000	350,000	350,000	350,000	350,000		2,800,000
Strategic studies and strategy advice	2,570,000		2,570,000										2,570,000
Airspace Users	3,200,000		400,000	400,000	400,000	400,000	400,000	400,000	400,000	400,000			3,200,000
Professional Staff Associations	2,300,000		300,000	300,000	300,000	300,000	300,000	300,000	250,000	250,000			2,300,000
Airports Expertise	1,750,000		250,000	250,000	250,000	250,000	250,000	250,000	250,000				1,750,000
Scientific Committee	960,000		120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000			960,000
Young Scientist Award (including travel costs)	70,000		10,000	10,000	10,000	10,000	10,000	10,000	10,000				70,000
Total needs	570,000,000	0	128,412,066	88,648,000	16,949,934	149,855,000	56,430,000	114,855,000	5,380,000	5,120,000	4,350,000	0	570,000,000

PAYMENT APPROPRIATIONS												
Reference	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
ER 1			9,490,000	5,694,000	8,541,000							23,725,000
ER 2				9,490,000		5,694,000	8,541,000					23,725,000
ER 3					9,490,000		5,694,000	8,541,000				23,725,000
ER 4							9,490,000		7,117,500	7,117,500		23,725,000
IR 1		81,678,336	54,087,500	11,744,721	11,744,721	11,744,721						171,000,000
IR 2					84,000,000	35,700,000	17,100,000	17,100,000	17,100,000			171,000,000
IR 3							59,500,000		12,750,000	12,750,000		85,000,000
Programme support			4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000		32,000,000
Experts call evaluations		700,000	350,000	0	700,000	0	700,000	0	0			2,450,000
Experts for deliverables and project reviews			350,000	350,000	350,000	350,000	350,000	350,000	350,000	350,000		2,800,000
Strategic studies and strategy advice			642,500	642,500	642,500	642,500						2,570,000
Airspace Users		400,000	400,000	400,000	400,000	400,000	400,000	400,000	400,000			3,200,000
Professional Staff Associations		300,000	300,000	300,000	300,000	300,000	300,000	250,000	250,000			2,300,000
Airports Expertise		250,000	250,000	250,000	250,000	250,000	250,000	250,000				1,750,000
Scientific Committee		120,000	120,000	120,000	120,000	120,000	120,000	120,000	120,000			960,000
Young Scientist Award (including travel costs)		10,000	10,000	10,000	10,000	10,000	10,000	10,000				70,000
Reserve to cover operational expenditure beginning of 2024			3,648,000									
Total needs	0	83,458,336	73,648,000	33,001,221	120,548,221	59,211,221	106,455,000	31,021,000	42,087,500	24,217,500	0	570,000,000

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