sesar
JOINT UNDERTAKING

SESAR 2020 CLOSURE REPORT

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Photo credits

Front cover: ©stock.adobe.com/indyntk; Page 6 ©PROSA/Enaire; Page 10 ©RETINA, ©Shutterstock; Page 11 ©SESAR JU; Page 13 ©NATS; Page 14 ©OAUO PJ.07; Page 15 ©IAO; Page 17 ©SESAR JU; Page 20 ©Volocopter; Page 21 ©SESAR JU; Page 22 ©Shutterstock; Page 24 ©Envision; Page 26-28 ©Shutterstock

Luxembourg: Publications Office of the European Union, 2024

PDF ISBN 978-92-9216-213-9 doi:10.2829/298861 MG-02-24-663-EN-N

CONTENTS

LIST OF FIGURES

LIST OF TABLES

SESAR 2020 - AT A GLANCE

19 funding members
Representing 37 legal entities directly participating in SESAR calls

39 countries

454 participating organisations

307 private companies **24** public entities

77 high education entities **33** research entities **13** other entities

157 projects executed

86 ER **35** IR **36** VLD

44%
of the ATM Master Plan Phase C delivered

468
prototypes produced

30.000
flight trials done

95
test sites across Europe

54
solutions implementation ongoing

137
solutions delivered

69
solutions deployed

1 Executive summary

This report outlines the results of the SESAR 2020 research and innovation (R & I) programme. It captures the achievements from 2015 to 2023, reports on the use of the funds allocated to the programme and draws lessons and identifies challenges in view of a successful implementation of the Digital European Sky programme, SESAR 2020's successor.

Background

The Single European Sky ATM Research Joint Undertaking (SESAR JU) ([1]) was first established by an EU regulation in 2007 to modernise European air traffic management (ATM), coordinating and concentrating all relevant research and development activities in Europe, including the maintenance of the European ATM Master Plan. In 2014, the joint undertaking was extended and a second programme of R & I activities, called SESAR 2020, got underway.

Over the course of SESAR 2020, the SESAR JU ensured the involvement of stakeholders from across the ATM sector in Europe. A total of 454 beneficiaries participated in the programme, namely air navigation service providers, airspace users, professional staff associations, airports and the manufacturing industry, along with the scientific community.

In 2021, the SESAR 3 Joint Undertaking ([2]) was established as the successor to the SESAR JU, to oversee the completion of SESAR 2020 activities and manage the new Digital European Sky (DES) programme of R & I.

Programme achievements and solutions delivered

During the lifetime of SESAR 2020, the SESAR JU funded 157 projects ([3]) resulting in the development of 468 prototypes and 836 feasibility activities and carrying out over 30 000 demonstration flights.

As a result, 137 SESAR Solutions were delivered to the aviation community through the SESAR release process. Details about the solutions delivered are available at the SESAR Solutions Catalogue: https://www.sesarju.eu/catalogue.

Contents of the report

The purpose of this document is to:

1. highlight the added value of SESAR 2020 R & I activities upon the closure of the programme;
2. report on the use of the funds allocated to SESAR 2020;
3. outline lessons to be drawn from the Digital European Sky programme.

Key takeaways

The SESAR 2020 programme was an integral part of EU efforts to both promote growth in the economy and help deliver the sustainable and smart mobility strategy ([4]). A technologically enhanced and performance-driven ATM system is a critical element for the sustainability of the aviation sector. SESAR defines, develops and deploys operations and technologies to transform ATM in Europe. SESAR 2020 was essential to maintaining Europe's position as a world leader in aviation.

([1]) When referring to the 'joint undertaking', this report refers to both the SESAR JU and the SESAR 3 Joint Undertaking. While being two different legal entities, established by two different legal acts, both have driven and managed the SESAR 2020 programme; the SESAR JU from 2015 to 2021 and the SESAR 3 Joint Undertaking from 2021 to 2024.

([2]) Council Regulation (EU) 2021/2085, known as the Single Basic Act.

([3]) This includes 149 projects funded under Horizon 2020, six projects under the Connecting Europe Facility and one project under assigned revenues from the European Parliament.

([4]) Sustainable and smart mobility strategy: https://transport.ec.europa.eu/transport-themes/mobility-strategy_en.

From 2015 to 2023, the SESAR JU was successful in managing a framework for research cooperation, which brought together all relevant stakeholders in ATM (e.g. air navigation service providers, airports, airspace users, the manufacturing industry, the scientific community and professional staff), along with key national and European entities such as the European Commission, Eurocontrol, the European Aviation Safety Agency (EASA) and the European Organisation for Civil Aviation Equipment (Eurocae). SESAR 2020 triggered a number of standardisation and regulatory needs related to the industrialisation of new technologies and operations, and it also provided key inputs for national and European entities to develop necessary new standards and regulations.

From a financial point of view, the SESAR JU managed SESAR 2020 very efficiently. It should be noted that the joint undertaking is responsible for a complex programme that goes beyond the mere management of grants. It has had to maintain alignment between projects, policy initiatives and the European ATM Master Plan, while bridging research activities with industrialisation. Finally, the joint undertaking supports the global outreach of the European approaches to the worldwide evolution of the ATM systems. In the 2015–2023 timeframe, the expenditure in administrative costs to perform these activities was less than 4.5 % of the total contribution to the programme, a figure below the 5 % benchmark.

The execution rate of the budget allocated to SESAR 2020 projects reached 94 %, with a cumulative residual error rate under 2 %.

2 Achievements of the SESAR 2020 programme (2015–2023)

2.1 European ATM Master Plan

In accordance with Article 1(5) of Regulation (EU) 721/2014, the joint undertaking is responsible for the European ATM Master Plan ([5]) (hereafter referred to as the 'Master Plan'), the roadmap for ATM modernisation, which was first adopted in 2009.

During the reporting period, the SESAR JU oversaw two significant updates to the plan, in 2015 and again in 2019, approved both times by the SESAR JU Administrative Board. These updates took into account the changing landscape of aviation, such as the increase in traffic, growing environmental concerns and the new entrants as users of the European airspace. The updates included refinements to the vision, an alignment between performance and technology, details on research, innovation and deployment activities, and a roll-out of the vision in four phases (A–D) extending to 2040.

At the end of SESAR 2020, with the delivery of its solutions, 44 % of phase C of the Master Plan was completed. The first industrial research call under the Digital European Sky programme included a specific work area and budget to complete the research and development activities of this phase. The selected projects will deliver the 22 SESAR solutions needed to achieve an additional 44 % of phase C and its performance ambitions, in particular on the following key performance areas: fuel efficiency and carbon dioxide (CO_2) emissions (with an expected reduction of 3.6 %), predictability, punctuality (with an expected reduction of delays per departure of 18 %) and technology cost (with an expected reduction of cost per flight of 31 %). The remaining elements of phase C are addressed with the most recent update of the Master Plan in 2024.

Complementary to the Master Plan, the Airspace Architecture Study ([6]) was published in 2019, which proposed a new approach to Europe's airspace architecture leveraging advanced technologies and decoupling service provision from local infrastructure.

The study proposed to optimise airspace configuration and design from a European network point of view, connecting airports and taking due consideration of major traffic flows across Europe. A transition plan was also published in 2019 outlining three key operational and technical measures needed to set in motion the transformation changes described in the study. The proposed approach gained widespread consensus by the ATM community and was integrated into the future architecture as published in the 2020 edition of the Master Plan.

([5]) European ATM Master Plan: https://www.sesarju.eu/masterplan.

([6]) Airspace Architecture Study https://www.sesarju.eu/node/3253.

2.2 SESAR 2020 project results

The SESAR 2020 R & I programme comprised three research strands: exploratory research, industrial research and very-large-scale demonstrations (VLDs). Together, these strands made up an innovation pipeline through which ideas were transformed into tangible solutions for industrialisation.

2.2.1 Exploratory research results

SESAR 2020's exploratory research provided the necessary wide-ranging scientific support to enable ATM change and helped develop emerging technologies and methods. Results from these projects provided basic principles, a level of maturity known as technological readiness level 1 (TRL 1), or went beyond formulating some technology concepts, achieving TRL 2 ([7]).

SESAR 2020 exploratory research comprised two areas: fundamental research activities related to the ATM thematic area of 'excellent science & outreach', focusing on new concepts for ATM beyond those identified in the Master Plan; and ATM application-oriented research, building on the results from fundamental research, providing a bridge to higher maturity industrial research activities and consequently engaging with a range of industrial stakeholders.

A total of 38 projects were carried out in the ATM thematic area of 'excellent science & outreach', while 40 projects were implemented in the area of application-oriented research. A further eight projects were awarded within exploratory research, following a mandate given to the SESAR JU to coordinate research and development activities related to U-space and drone integration and the subsequent publication of the SESAR U-space Blueprint ([8]). These projects performed research in early U-space concepts, making use of mature technologies. The 86 awarded projects were selected out of a total of 280 eligible proposals, amounting to a 31 % success rate. Of the proposals not awarded, some 100 proposals passed the evaluation threshold, and although the SESAR JU had an undoubted interest in them, they could not be awarded due to budgetary limitations. It is estimated that an additional budget of around EUR 75 million could have allowed the funding of those 100 proposals.

The SESAR 2020 multiannual work programme ([9]) organised 'excellence science & outreach' activities (TRL 0–1) around six main research themes:

- automation, robotics and autonomy;
- complexity, data science and information management;
- environment and meteorology for ATM;
- performance, economics, legal and regulation;
- ATM's role in intermodal transport; and
- communications, navigation and surveillance (CNS) for ATM.

Figure 1 shows the distribution of projects per topic for 'excellent science & outreach'.

The research activities performed in the application-oriented research area were organised according to four key areas (known as key features), which were aligned with SESAR 2020's industrial research to facilitate the transition of promising results towards further industrial research:

- high-performing airport operations;
- enabling aviation infrastructure;
- advanced air traffic services;
- optimising ATM network services.

Figure 2 shows the distribution of application-oriented exploratory research projects across the various key features.

In addition, a coordination and support action project, the knowledge transfer network project known as Engage, supported the SESAR JU in communication, scientific events, developing a research knowledge repository and helping develop the SESAR Digital Academy, which is focused on learning and development for the community. The network provided significant

([7]) The definitions of the different TRLs, as being consistently used throughout the programme, can be found in Section 2.2.1, and in particular in Section 2.2.1.1, of the SESAR 3 multiannual work programme: https://www.sesarju.eu/sites/default/files/documents/GB/2022/GB(D)02-2022%20SESAR%203%20Multiannual%20Workprogramme%202022-2031.pdf.

([8]) U-space Blueprint: https://www.sesarju.eu/u-space-blueprint.

([9]) Administrative Board Decision 5/2015.

value across the whole SESAR 2020 programme, such as supporting future fundamental research and transferring results towards application-oriented activities.

The projects on CNS systems and equipment focused on both ground systems and airborne systems, including general aviation, to facilitate a better integration of this sector. It should be noted that while automation and digitalisation topics were dealt with more generally in the early stages of research, activities related to research in CNS systems were more mature and well ahead in the innovation pipeline.

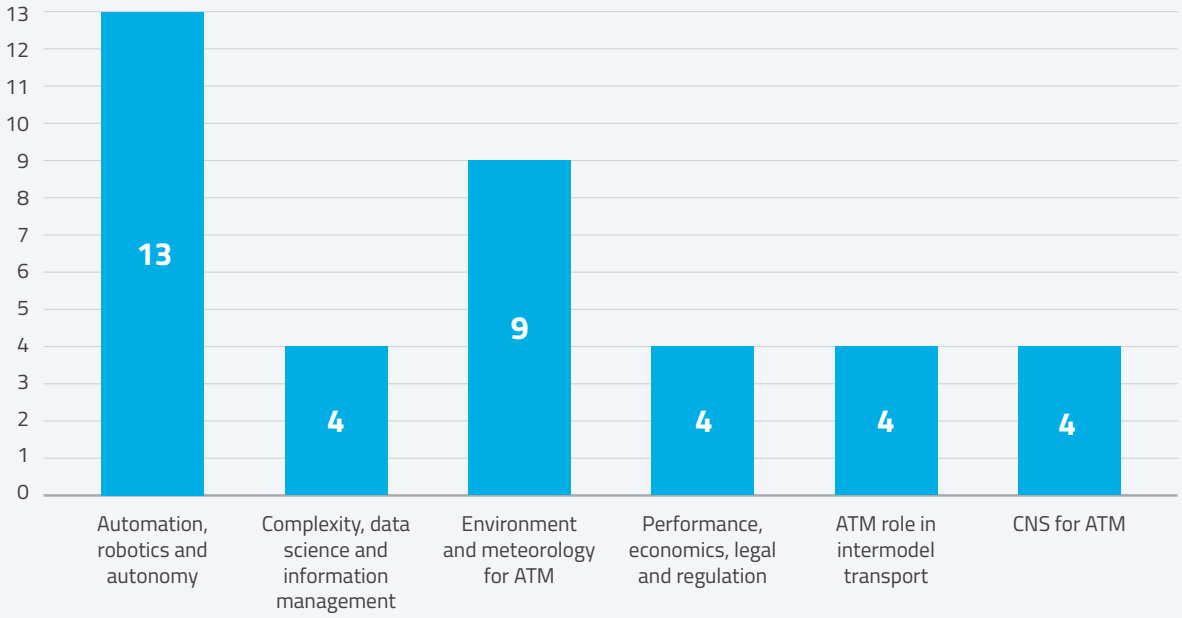


FIGURE 1: **DISTRIBUTION OF EXPLORATORY RESEARCH (ER) PROJECTS PER TOPIC IN THE 'EXCELLENT SCIENCE & OUTREACH' THEMATIC AREA**

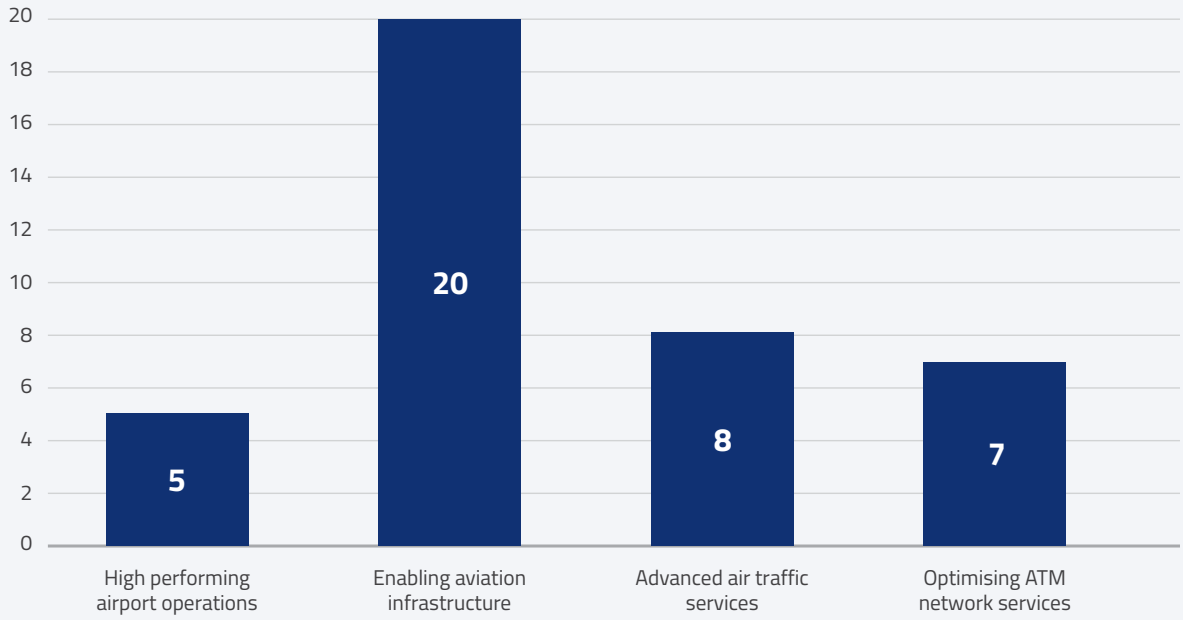


FIGURE 2: **DISTRIBUTION OF ER PROJECTS PER KEY FEATURE IN THE APPLICATION-ORIENTED RESEARCH THEMATIC AREA**

Examples of exploratory research projects

Retina – Resilient synthetic vision for advanced control tower air navigation service provision

The project showed how augmented reality can improve tower controllers' situational awareness by no longer being limited by what the human eye can physically see from the tower windows.

The concept allows the controller to have a heads-up view of the airport traffic even in low-visibility conditions, similar to augmented or fully synthetic vision currently possible in the cockpit. As access to more trustable data increases, the range of enhanced operations will be increased.

The project achieved a TRL 4, and the results were fed into the SESAR innovation pipeline for further exploitation as part of the SESAR industrial research project 'Digital technologies for towers' (PJ.05).

www.sesarju.eu/projects/retina

https://www.sesarju.eu/projects/DTT

USEPE – U-space separation in Europe

The project explored potential separation methods throughout the strategic and tactical flight planning phases, including defining the participants responsible for making decisions. The research considered which participant should be the predetermined separator (the drones themselves or the U-space system) throughout the strategic and tactical planning phases before defining a set of concepts to provide safe separation for different kinds of drones.

To simulate the different concepts and assess the impact of the key performance areas of safety, capacity and efficiency, USEPE developed and made available new modules in Bluesky, an open-access simulator. These included a city module, a path planning module, a strategic deconfliction module and an airspace segmentation module. The findings were shared with relevant stakeholders as a first step in creating an initial concept of operations for an urban airspace separation management system.

www.sesarju.eu/projects/USEPE

Through its exploratory research projects, SESAR 2020 engaged with over 227 beneficiaries, including 69 education institutions and 26 research organisations coming from 15 EU Member States. Those Members States are Belgium, Czechia, Denmark, Germany, Ireland, Greece, Spain, France, Croatia, Italy, the Netherlands, Austria, Portugal, Finland and Sweden. It also received contributions from organisations in seven non-EU countries: Israel, Norway, Russia ([10]), Serbia, Switzerland, Türkiye and the United Kingdom.

([10]) The contribution of Russia was terminated before the start of the Russian war of aggression against Ukraine.

'Exploring the boundaries of air traffic management' captures the results of completed exploratory research projects and the SESAR knowledge transfer network project, Engage. Active between 2016 and 2020 and between 2020 and 2022, the project brought together academic and industry partners, such as universities, small and medium-sized enterprises (SMEs), research centres, airlines, manufacturers and air navigation service providers from across the EU and from the non-EU countries associated with SESAR. The projects explored concepts and technologies not only in aviation and ATM but also in other sectors, such as automotive, robotics or system engineering, and in other safety-critical industries.

2.2.2 Industrial research and validation results

SESAR 2020 industrial research and validation activities facilitated the migration of ideas from exploratory research to applied research and towards pre-industrialisation, validation, large-scale demonstration and final preparation for deployment. Between 2015 and 2023, activities in this research strand had to overcome the difficulties arising from external events such as COVID-19 and the Russian war of aggression against Ukraine. Notwithstanding these circumstances, the results proved excellent.

During the period of this report, 35 projects were completed, out of which 30 were responsible for developing and validating ATM solutions, while five provided transversal support to the SESAR JU.

SESAR Solutions refer to new or improved operational procedures or technologies that aim to contribute to the modernisation of the European and global ATM system. Framed within the European ATM Master Plan, these solutions address all parts of the ATM value chain, from airports and air traffic services to the network, along with the underlying systems' architectures and technological enablers, which are validated in real day-to-day operations.

www.sesarju.eu/catalogue

Figure 3 shows the distribution of industrial research projects across the key features.

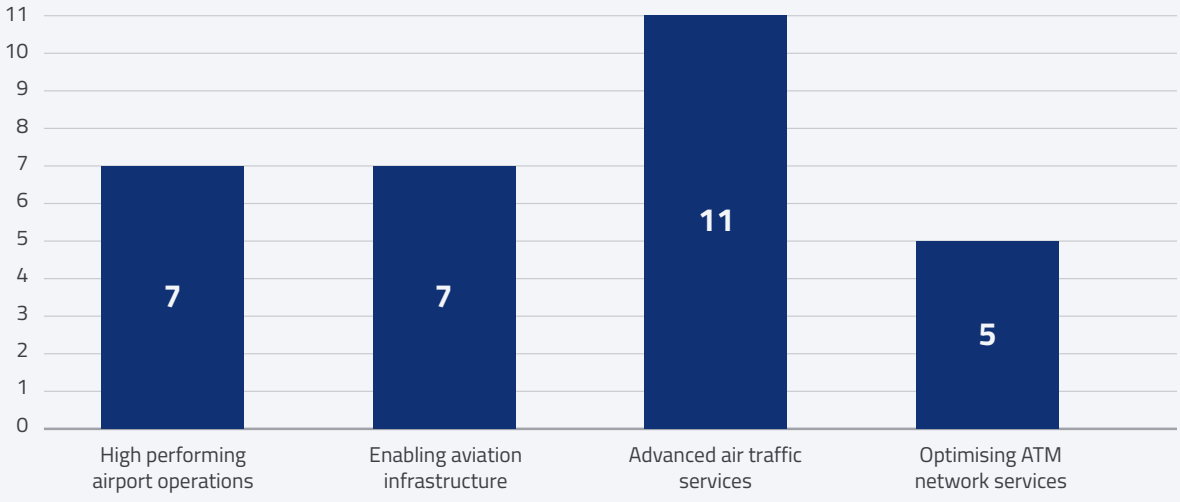


FIGURE 3: **DISTRIBUTION OF INDUSTRIAL RESEARCH (IR) PROJECTS PER KEY FEATURE**

Figure 4 shows, for each key feature, the contribution of projects to specific topics.

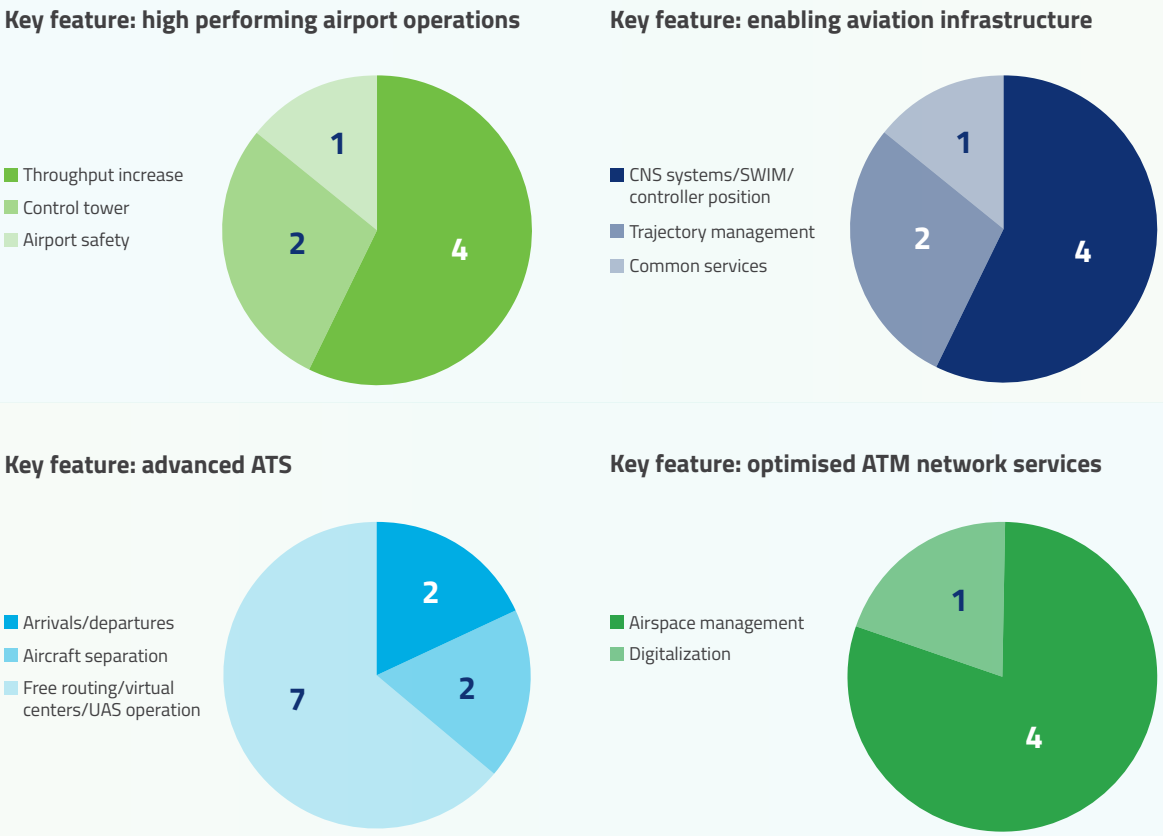


FIGURE 4: **DISTRIBUTION OF IR PROJECTS PER TOPIC FOR EACH FEATURE**

SESAR 2020 made significant progress in a range of areas, from virtualisation and interoperability to trajectory-based operations and enabling technologies for airport total management. The programme leveraged modern technologies to support the future airspace architecture and developed capabilities to address today's challenges of resilience, scalability, climate impact and the integration of new entrants.

Within the key feature of 'high-performing airport operations', SESAR 2020 addressed the need for increasing airport throughput, covering movements both on airport surfaces and particularly on the runways, addressing both capacity and safety, complemented by the airspace–airport integrated approach. The research for control towers focused mainly on their digitalisation, for example, in the further application of remote towers with a multiple remote tower module, which pools air traffic control officers (ATCOs), who provide their services to airports on demand; or on data exchange for total airport management to increase predictability and support collaborative decision-making based on timely information.

Under the key feature of 'enabling aviation infrastructure', and in relation to the trajectory-based operations, the aim was to reduce controller workload and increase airspace capacity by establishing an integrated view of all flight trajectories, including military, based on four-dimensional aircraft trajectories (latitude, longitude, altitude and time). SESAR 2020 industrial research validated the downlinked aircraft trajectories from the flight management system to the ground to enable controllers to identify potential inconsistencies between the route as filed in the flight plan and the trajectory actually flown. The research also developed technical specifications for the European datalink common service to distribute data downlinked from the aircraft to air traffic control, Network Manager, airlines and other stakeholders.

Regarding the key feature of 'optimising ATM network services', projects mainly focused on airspace management, including demand–capacity balance, to optimise the operations of the airspace users.

In the key feature of 'advanced air traffic services', optimisation of en-route operations focused on trajectory management, where research efforts have primarily been on virtual centres, advanced air traffic control controller tools and trajectory-based operations. Virtual centres aim to give air navigation service providers added flexibility and resilience by decoupling services such as flight data, radar and weather information from the physical controller working position to increase service continuity. SESAR 2020 tested different architectures and delegated airspace between different ATM service providers to demonstrate the technical viability of the concept.

Industrial research and fast-track activities also included work on the integration of new entrants using either U-space services, including between U-space and ATM, or for higher airspace operations, where operations inevitably pass through controlled airspace.

SESAR 2020 delivered Europe's U-space Blueprint, which sets out how drones will be integrated into the lower airspace and the concept of operations ([11]), which details what U-space means operationally in the context of the EU's U-space regulations. Between 2017 and 2022, extensive flight trials in urban and non-urban environments helped to shape U-space services and concept definition by delivering deployable solutions to help scale up this sector. The details on the VLDs can be found in Section 2.2.3. of this report. In addition, the AURA - ATM U-space Interface project laid the foundations for the integration of the new entrants in the air traffic environment, developing and validating a collaborative ATM/U-space concept of operations based on U-space services information exchanges with ATM systems.

Considering higher airspace, SESAR 2020 delivered a concept of operations to enable scalable operations above the flight levels where conventional air traffic operates. An array of new vehicles ranging from unmanned balloons, airships and solar planes to super- and hyper-sonic vehicles are going to seize new business opportunities in this space. Therefore, research continues under the Digital European Sky project 'European concept for higher airspace operation phase 2'.

SESAR 2020 paid particular attention to climate impact, focusing on new technologies and procedures to improve air traffic's environmental performance, while work progresses on other high-impact innovations, such as sustainable aviation fuels and new aircraft. Much of the focus of these climate-improving solutions was on making taxi-out and runway operations more predictable and efficient, reducing holding patterns and vectoring in terminal airspace upon arrival, and optimising trajectories with initial four-dimension (i4D) trajectory, among other technologies. All of these solutions bring fuel savings, while some also support local environmental performance objectives through noise mitigation and air quality improvements.

The following two projects are examples among the extremely wide range of industrial research projects funded.

PROSA – Separation management and controller tools

In the context of virtual centres and the delegation of air traffic services, PROSA delivered two solutions that contributed to the decoupling of air traffic service provision from data provision.

For automation support, a solution was delivered on attention guidance to focus situational awareness and attention, and in the context of automatic speech recognition, a solution was developed that proved to reduce workload and improve flight efficiency.

Virtual centres allowed the air traffic services delegation between two separate air traffic service units (ATSU) to be performed as one virtual centre, relying on data being supplied from a

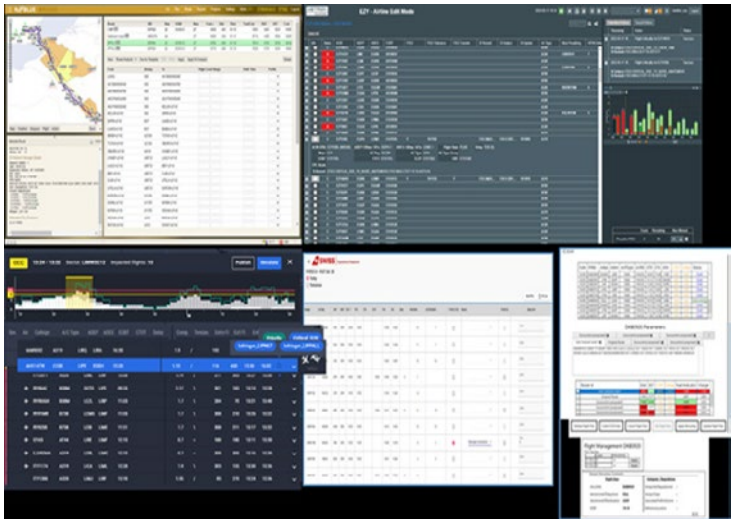
([11]) The fourth edition of the concept of operations document can be found at: https://www.sesarju.eu/sites/default/files/documents/reports/U-space%20CONOPS%204th%20edition.pdf.

single aeronautical data service provider (ADSP) in a 'one-ADSP-to-several-ATSUs' configuration. This configuration enabled the application of several operational scenarios based on traffic and organisational needs, such as a night-time scenario, a fixed-time scenario and a contingency scenario. In the context of automation and support for ATCOs, the project delivered two solutions that reached TRL 6.

On automation support, the attention guidance solution permitted the ATCO to maintain focus on two important skills that controllers need to keep at a high level when controlling aircraft on a radar screen, situational awareness and attention. PROSA used an eye tracker system to examine salient visual stimuli to intelligently prioritise the events and guide the operator's attention to a potential hotspot or conflict area on the radar screen if the event went unnoticed by the controller for a given time frame. The solution reached TRL 6.

An automatic speech recognition solution was also developed, using integrated artificial intelligence and machine learning algorithms, to 'implement text predictions based on surveillance data'; 'create ATM commands based on existing ATC concepts'; and a combination of both to provide further applications for the controller working position. This successfully proved the benefits of translating audio signals and was proven to help reduce workload and improve flight efficiency. The solution reached TRL 6.

Optimised airspace users' operations



This project defined and validated improved airspace users' processes and tools related to ATM network operations. The current ATM environment, based on static flight plans, is evolving towards trajectory-based operations to improve airports and ATM network performance. By developing requirements and validating procedures and workflows for flight/wing operations centres, the project defined interactions between ATM stakeholders, including the Network Manager, for trajectory definition, ensuring continuity in the collaborative decision-making process.

Integrating airspace users' priorities and preferences in collaborative processes at airports and in network demand capacity balancing processes throughout the trajectory life cycle enables processes to perform multi-criteria optimisation tasks involving many stakeholders.

The project delivered solutions offering three important operational improvements, namely;

- Enabling airspace users to proactively share information about their critical flights with the Network Manager (NM) and local flow managers;
- Enabling local flow managers to share with the NM and airspace users their information on protection hotpots;
- Optimising user-driven prioritisation process (UDPP), reducing the costs of air traffic flow and capacity management (ATFCM) in the context of arrival flow management at congested airports.

This project's three solutions, which are ready for implementation.

Five SESAR 2020 industrial research projects were dedicated to transversal activities supporting the entire programme.

- **AMPLE 1 & 2** (28 participants) were instrumental in ensuring the maintenance, update and alignment of the three levels of the Master Plan (executive, planning and architecture, implementation) and its associated portal. As a result of this work, a significant update of the Master Plan was completed in December 2019 and was adopted by the Administrative Board of the Joint Undertaking as its 2020 edition ([12]).
- **Content Integration 1 & 2** (26 participants) supported the SESAR JU in the assessment of the maturity, consistency and coherence of the solutions, ensuring their interoperability and readiness for deployment. They also maintained SESAR's performance framework against the target ambitions of the Master Plan.
- **Seabird** (11 participants) addressed validation and demonstration engineering associated with SESAR 2020. The project provided a system engineering data management framework to support the coherent development and delivery of SESAR Solutions. The project identified a set of strategic validation tools and interoperability solutions to improve the SESAR 2020 validation process.

In total, industrial research activities involved 149 beneficiaries (e.g. large companies, SMEs, industry and universities), mainly members of the SESAR JU. This participation was spread over 20 Member States: Belgium, Bulgaria, Czechia, Denmark, Germany, Ireland, Spain, France, Croatia, Italy, Lithuania, Hungary, Malta, the Netherlands, Austria, Poland, Portugal, Romania, Slovakia and Sweden. In addition, the programme saw the participation of organisations in seven non-EU countries: Australia, Canada, Norway, Serbia, Switzerland, the United Kingdom and the United States. Altogether the research projects engaged around 2 000 industry experts.

2.2.3 Very-large-scale demonstration results

Between the end of 2018 and the end of 2023, the SESAR JU carried out 36 VLDs responding to the key features of the SESAR 2020 programme. In total, 29 VLD projects under Horizon 2020 were completed, while a further six addressing U-space were carried out and funded under the framework of the Connecting Europe Facility (CEF). Finally, one large-scale demonstration project took place addressing geofencing, financed by assigned revenues from the European Parliament.

The demonstrations were designed to bridge the gap between the development and deployment phases in SESAR. The VLDs used early versions of end-user systems and could also include the integration of new technology or procedure elements into existing systems. They aimed at demonstrating the suitability of prototypes in an operational or close-to operational environment. Consequently, the results of these demonstrations correspond to a level of maturity of TRL 6 and, in nine cases, to TRL 7. When so required, the EASA, the national supervisory authorities and the national aviation authorities played a key role in these activities by providing the necessary approvals for the new equipment and operations that were involved the demonstrations.

Overall, these projects resulted in around 30 000 actual demonstration flights, producing a wealth of data to support the next steps and engaging with stakeholders responsible for deployment.

Figure 5 provides information on the distribution of projects per key feature. The VLDs financed with CEF funds or assigned revenues from the Parliament have been included in the assessment.

([12]) European ATM Master Plan 2020: https://www.sesarju.eu/masterplan2020.

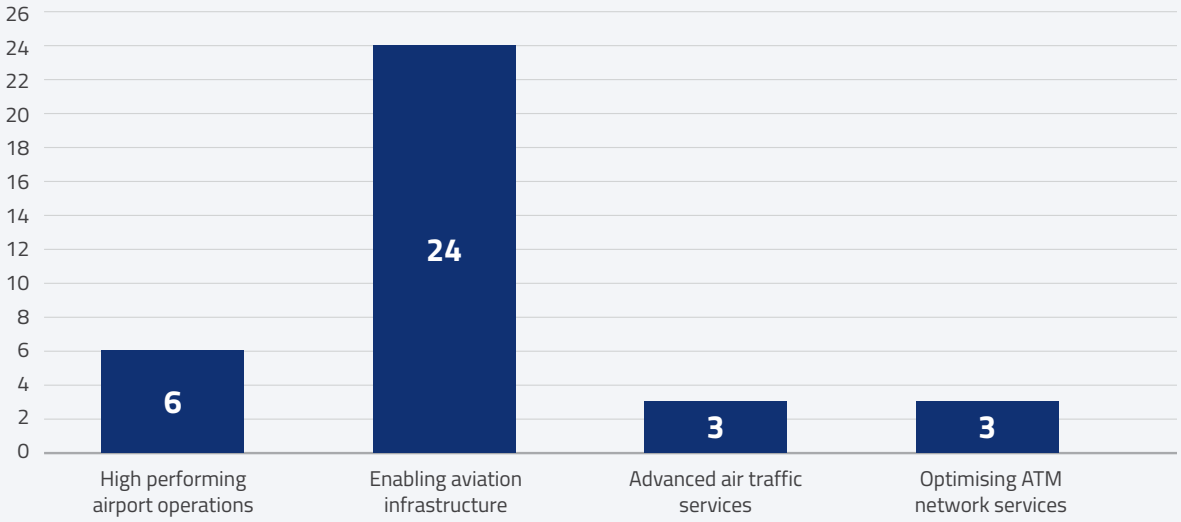


FIGURE 5: **DISTRIBUTION OF VLD PROJECTS PER KEY FEATURE**

A stand-out demonstration was 'ALBATROSS – The most-energy-efficient flying bird' ([13]), which delivered results that go beyond the scope of ATM. It carried out 1 000 demonstration flights showcasing mature operational SESAR solutions with potential fuel and CO_2 savings. ALBATROSS was financed with Horizon 2020 funds.

The distribution of the topics addressed by the different VLD projects, per topic, in the key features of 'high-performing airport operations' and in 'enabling aviation infrastructure' are shown in Figure 6.

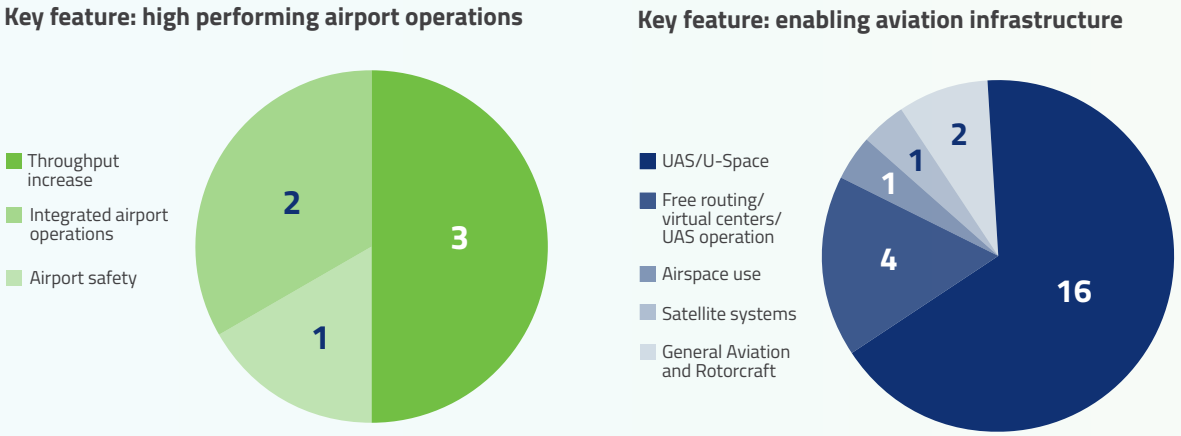


FIGURE 6: **DISTRIBUTION OF TOPICS ADDRESSED BY VLD PROJECTS IN 'HIGH-PERFORMING AIRPORT OPERATIONS' AND IN 'ENABLING AVIATION INFRASTRUCTURE'**

Concerning the key feature of 'advanced air traffic services', the related projects dealt with testing the extension of arrival management to the en-route phase of flight. Similarly, for the key feature 'optimisation of ATM network services', the demonstrations involved the Network Manager and several other main stakeholders in the air navigation domain to improve the collaboration among them.

The efforts made in the field of geofencing, drones and U-space are remarkable, which illustrates the interest of the aviation community in these areas. This is consistent with the trend of moving drone-related research activity into the innovation pipeline.

([13]) https://www.sesarju.eu/projects/ALBATROSS.

Moreover, the results of the projects performed in the geofencing, drone and U-space fields provided useful recommendations for the two main EU regulations on U-space (Commission Implementing Regulation (EU) 2021/664 and Commission Implementing Regulation (EU) 2019/947).

It is also noticeable the efforts made in the demonstrations on the exchange of flight and trajectory information with ground infrastructure, which shows the continuous support of the research activities in achieving a reliable and efficient data link.

In total, 188 entities (public, private, large companies, SMEs, industry, universities, etc.) participated in these VLDs. These entities came from 26 Member States, but also seven entities from seven non-EU countries (Cabo Verde, Israel, Norway, Serbia, Switzerland, the United Kingdom and the United States) participated in the activities. This shows that the VLDs attracted participation from a large number of countries beyond those involved in the earlier stages of development.

2.2.4 SESAR Solutions

SESAR 2020 delivered SESAR Solutions ready for industrialisation and deployment. These refer to new or improved operational procedures or technologies to contribute to the modernisation of the European ATM system. At the end of the programme, 137 SESAR Solutions were delivered.

The distribution of the SESAR Solutions across the key features reflects the technological nature of the SESAR 2020 programme and is presented in Figure 7.

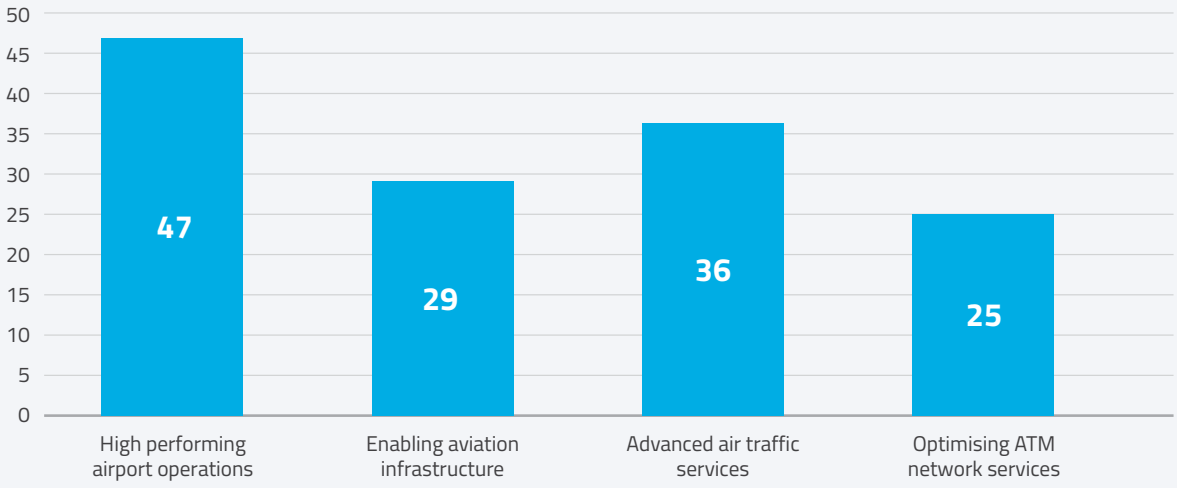


FIGURE 7: **NUMBER OF SESAR SOLUTIONS PER KEY FEATURE**

The SESAR Solutions reached the maturity level that implies a technology demonstrated in relevant industrial environments (a level of maturity known as TRL 6, or V3). They have the vocation to be deployed and put into operations. In that sense, at the closure of this report, 51 % of the 137 SESAR Solutions ([14]) were already deployed, which illustrates the efficacy of the innovation pipeline approach.

The rate of deployed solutions per key feature can be seen in Figure 8.

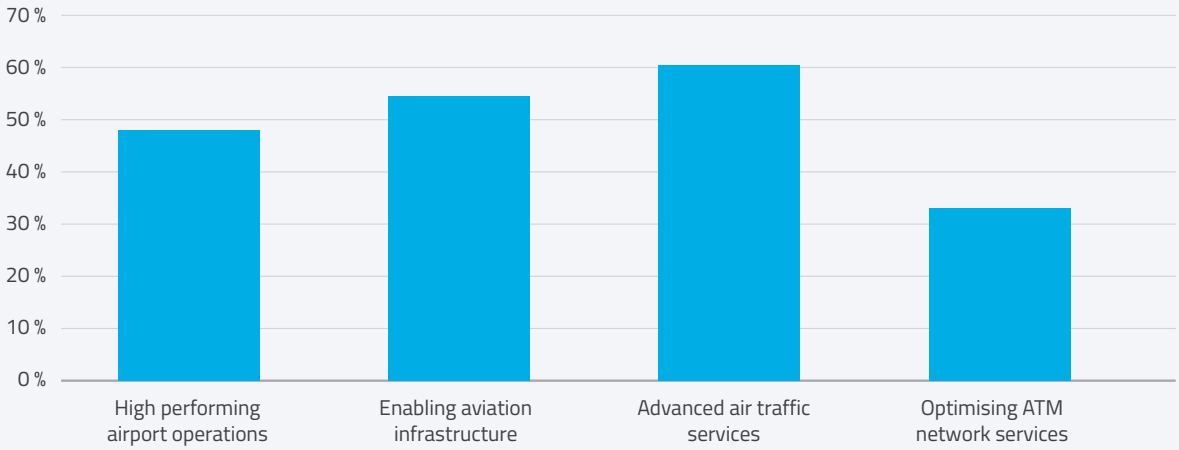


FIGURE 8: **DEPLOYMENT RATE (DEPLOYED/TOTAL) OF SESAR SOLUTIONS PER KEY FEATURE**

Two examples of SESAR Solutions are the following.

- **Multiple air traffic control tower module (MRTM).** This solution aims at reducing the costs of airport air traffic control while maintaining safe air traffic operations. It provides significant cost–benefit improvements in low-density airports, with no negative impact on safety or capacity. This solution allows controllers to maintain situational awareness for two or three airports simultaneously. Under the MRTM concept, the same number of controllers could handle a traffic volume of up to four times higher than the traffic handled in a single remote tower. The MRTM also integrates the airport into a broader network. Given that different types of aerodromes could be paired together in an MRTM, in the cases of traffic overload, aerodromes could be split between modules to reduce the workload per module. The MRTM was validated through several simulations, tests and exercises. It is suitable for all types of airspace users, including general aviation, rotorcraft and remotely piloted systems. It was recommended to update the European safety regulations related to multiple tower services to take this solution into consideration.
- **Total airport management (TAM).** TAM covers all the key airport processes. It addresses the integration of airports into the ATM network through the timely exchange of information between the network operations plan and the individual airport operations plans using system-wide information management (SWIM) technology. TAM prompts the evolution towards a 'performance-driven' airport through holistic monitoring of demand and capacity. This approach makes it possible for decision-making to be based on more reliable information. This increases predictability, flexibility and efficiency of airport operations. Solutions under this concept address environmental performance management; airside and landside performance management; connectivity between large airports and regional airports; and collaborative management at regional airports. Together, these solutions bring cost-efficiency benefits and improvements in predictability.

([14]) SESAR Solutions Catalogue

2.3 Support for deployment of SESAR 2020 results

2.3.1 Regulatory and standardisation support

The industrialisation of new systems and procedures based on SESAR Solutions may require the adaptation of existing standards or the elaboration of new ones. Between 2019 and 2023, Eurocae issued around 90 documents and related documentation to support the deployment of SESAR Solutions. New or amended documents have been published, planned or are in the process of elaboration. These documents relate to topics such as drones, air–ground data link, satellite navigation and virtual control centres. This is also the case for 25 documents of the European Telecommunications Standards Institute and around 50 Eurocontrol documents related to standards.

In parallel, EASA supported SESAR Solutions in terms of new or amended pieces of 'soft law' (e.g. acceptable means of compliance and guidance material). From 2015 to 2023, EASA published five documents on topics such as remote-control towers, drones and U-space.

2.3.2 The common projects

The deployment of the SESAR Solutions is articulated around either individual stakeholder business cases (voluntary take-up) or by regulation; (the so-called common projects, which are Commission implementing regulations mandating the coordinated and synchronised implementation of specific ATM functionalities). These specific ATM functionalities are built on SESAR Solutions that are ready for implementation. To that end, Commission Implementing Regulation (EU) 716/2014 (known as the pilot common project) was published in June 2014. In addition, Commission Implementing Regulation (EU) 2021/116 (known as common project 1) was published in February 2021. This regulation contains six ATM functionalities, which have been built on the basis of 25 SESAR Solutions. These solutions address topics such as arrival and departure management, free routing and route optimisation, dynamic sectorisation, SWIM, airport planning and runway optimisation, safety nets and awareness, and network planning.

The implementation dates for the various elements of the ATM functionalities range from the end of 2022 to the end of 2027. While many elements still have to be implemented between the end of 2024 and the end of 2027, several elements are already operational. For example, departure management synchronised with pre-departure sequencing, airspace management, advanced flexible use of airspace, initial free routing and short-term air traffic flow measures were implemented by the end of 2022. Also, the initial airport operations plan and the network operations plan were implemented by the end of 2023.

Currently, 348 SESAR deployment projects cover 76 % of the content of the regulation. Out of them, 293 projects (84 %) have been completed. As a result, around 42 % of the scope of common project 1 is already in operation ([15]).

2.3.3 Impact at a global level

In addition to its core task of modernising Europe's ATM system, during SESAR 2020, the SESAR JU pursued an international strategy in close coordination with the European Commission. The focus was on securing Europe's position as a global leader in ATM modernisation in support of the International Civil Aviation Organization (ICAO) Global Air Navigation Plan, promoting SESAR Solutions for global interoperability and harmonisation, and thereby supporting EU industrial leadership and competitiveness. To this end, the SESAR JU engaged actively in relations with the ICAO. Beyond its participation in the ICAO assemblies in 2016 and 2019, and in several other major ICAO conferences such as the Thirteenth Air Navigation Conference in 2018, the SESAR JU was instrumental in ensuring an effective European

([15]) According to the SESAR Deployment Manager dashboard, dated 6 May 2024 (https://www.sesardeploymentmanager.eu/).

contribution to the Global Air Navigation Plan and a strong alignment with the European ATM Master Plan.

Another frontline activity for the global outreach of the SESAR 2020 programme was the interaction with the Federal Aviation Administration of the United States under the EU–US memorandum of cooperation (MOC) in civil aviation research and development, which was extended in scope in 2017 to include deployment aspects. The objective of the MOC with the United States is to ensure global interoperability. Coordination between the SESAR JU and the Federal Aviation Administration's Next Generation Air Transportation System programme is the means to achieve it. Despite institutional and operational differences between Europe and the United States, some important milestones, such as a joint strategy for air/ground data communications, were achieved between 2015 and 2023.

Many other non-EU countries showed interest in the SESAR 2020 programme in the context of the EU's external aviation policy. Between 2015 and 2023, the SESAR JU signed MOCs or letters of intent with Georgia, Qatar and the United Arab Emirates. In addition, cooperation with Singapore and Japan was deepened during the period covered by this report.

3 Performance aspects

The performance of the SESAR 2020 programme was evaluated against the performance ambitions set out in the European ATM Master Plan (2020 edition) in relation to the full implementation of the SESAR vision. The assessment of these gains was captured in the performance assessment and gap analysis reports, a key deliverable of content integration and the AMPLE projects (see Section 2.2.2).

Figure 9, which is based on the reports, provides a high-level summary of the projected performance improvements at the end of the SESAR 2020 programme, assuming the full deployment of all available SESAR Solutions across the European Civil Aviation Conference geographical area. The values in brackets indicate the target improvements for 2040, as specified in the 2020 edition of the Master Plan.

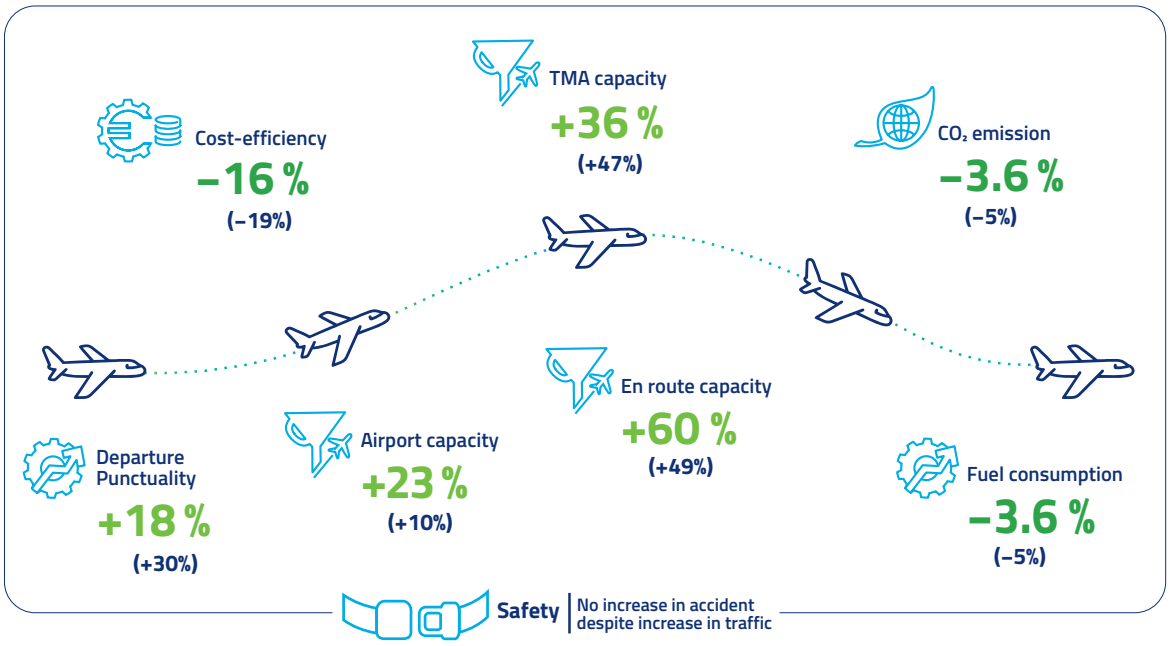


FIGURE 9: **PROJECTED PERFORMANCE IMPROVEMENTS AS A RESULT OF THE SESAR 2020 PROGRAMME**

Keeping in mind that the horizon timeline for the Master Plan is 2040, solutions delivered in SESAR 2020 already have the potential to reduce CO_2 emissions considerably. Airport and en-route capacity results have already exceeded the Master Plan's level of ambition. The increase in capacity in other flight phases is expected to reach the Master Plan level of ambition at the early stages of the Digital European Sky programme. The reduction of costs is already very close to the Master Plan level of ambition at the closure of SESAR 2020. High levels of safety are ensured with the solutions.

In conclusion, SESAR 2020 Solutions provide a significant contribution to the performance ambition in the Master Plan subject to their successful deployment.

4 Financial aspects

The SESAR 2020 programme presents very good financial results.

The investment in SESAR 2020 was originally estimated to be EUR 1 585 million, including EUR 85 million for exploratory research, EUR 1.2 billion for applied research and pre-industrial development and EUR 300 million for VLDs. Exploratory research activities were entirely paid for from the EU budget. The EU budget for the execution of the remaining activities was supplemented by contributions from industry and Eurocontrol. Following the signature of the various bilateral agreements with Eurocontrol and the SESAR JU members at the beginning of the programme, the initially planned investment amounted to EUR 1 374.38 million.

The SESAR JU was provided with additional assigned revenue under delegation agreements for EUR 11.3 million, including EUR 500 000 from the Parliament to organise a call for proposals for a geofencing demonstration, EUR 800 000 from the Commission to procure a study to develop a proposal for the future architecture of European airspace and EUR 10 million from the Commission from the CEF funds to organise a call for proposals on U-space demonstrations. The consolidated financial figures presented in this report include income/expenditure related to the Horizon 2020 programme and those assigned revenue received and implemented through these delegation agreements.

The overall contribution of the EU, Eurocontrol and industry reached a total of EUR 1 213.38 million. With this figure, the actual overall investment reached 88 % of what was initially planned.

The total net contribution, planned and realised, for the members, Eurocontrol and the EU, are shown in Table 1.

		Industry	Eurocontrol	EU	Total
Total net contribution *(million EUR)*	Planned	297.13	492.25	585	1 374.38
	Realised	304.27	343.05	566.06	1 213.38

TABLE 1: **PLANNED AND REALISED TOTAL NET CONTRIBUTION OF MEMBERS, THE EU AND EUROCONTROL**

At the end of the programme, the total net contribution by industry was 2.5 % higher than expected. This shows the positive response and commitment from the members.

Eurocontrol's contributions were mainly in kind, apart from 5 % provided as a cash contribution to the joint undertaking running costs and EUR 4.4 million in support of Maastricht Control Centre research activities. The initially estimated total net contribution was modulated during the programme with the real amount of effort needed across all grants to complement the work of the other members. At the end of the programme, the total net contribution by Eurocontrol was at almost 70 %.

The EU contribution on its side reached 96 % of the maximum available funds.

The running costs of the joint undertaking for the duration of the SESAR 2020 programme were EUR 54 124 370, which is almost 20 % less than the amount initially planned. Consequently, the expenditure in staff and administrative costs amounted to less than 4.5 % of the total contribution to the programme. This figure is well below the expected 5 % target; these savings contributed to increasing the funds available for research. An amount of EUR 7.8 million was indeed added to the initially planned exploratory research calls budget under SESAR 2020.

The SESAR 2020 projects show an overall co-financing ratio of 38 % of the beneficiaries' total in-kind contribution. As a result, the leverage effect of the programme is 1.65, meaning that every EUR 3 invested by the EU budget in the SESAR 2020 programme mobilised EUR 5 from Eurocontrol, the industry and other contributors. This also can be considered a proof of the success of the SESAR 2020 programme.

The joint undertaking was granted with the discharge of its accounts without any major issues during the entire SESAR 2020 programme. Its cumulative residual error rate was very low, as shown in Figure 10.

The audits of the SESAR 2020 programme have continued in 2024 and will possibly continue in 2025. Nevertheless, the trend of this error rate shows that the beneficiaries have a good knowledge of the Horizon 2020 expectations.

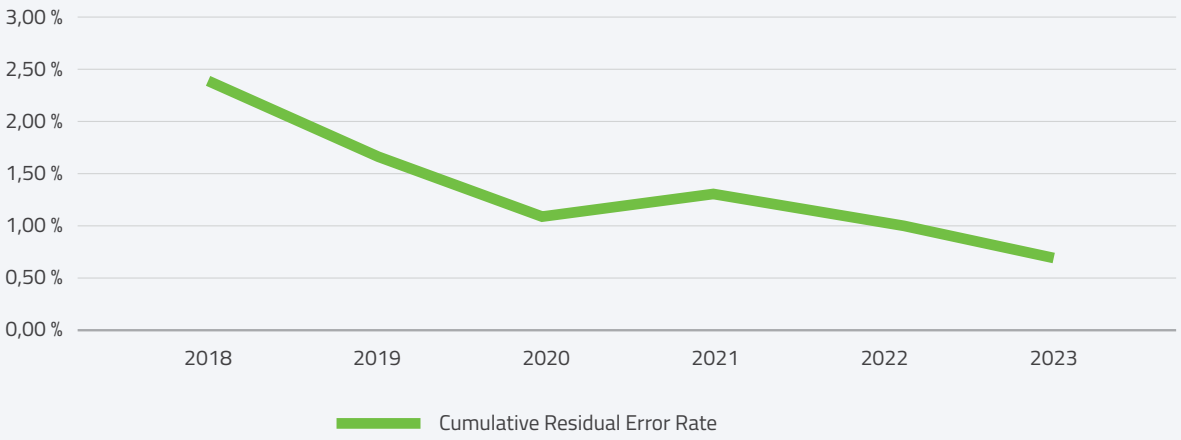
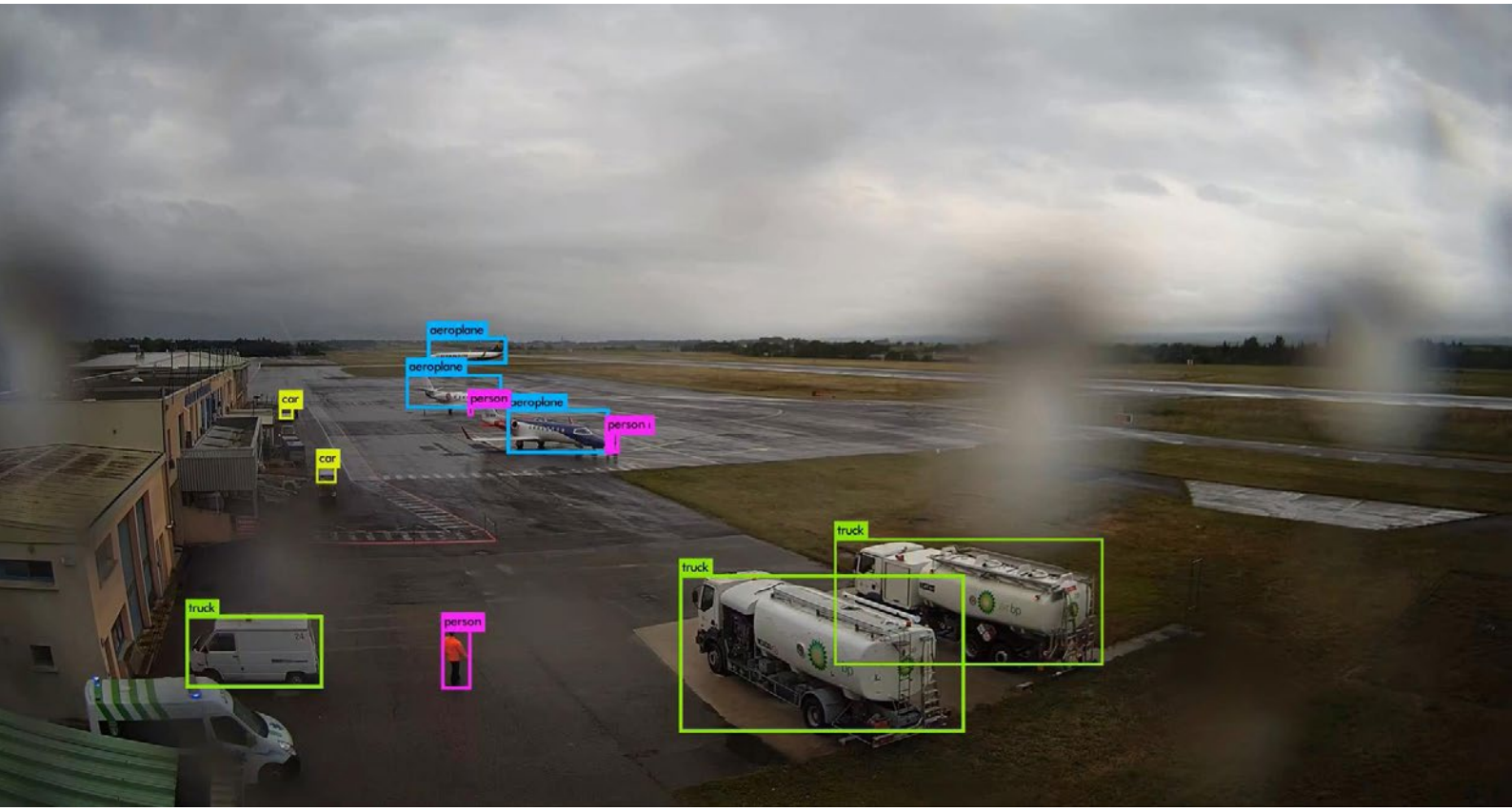


FIGURE 10: **CUMULATIVE RESIDUAL ERROR RATES FOR THE SESAR 2020 PROGRAMME**



5 Enablers of the achievements

5.1 Engaging stakeholders in the programme

5.1.1 Establishing membership of the joint undertaking

The SESAR JU originally brought together 16 industrial members along with the EU and Eurocontrol. With its extension in 2014 and the start of the SESAR 2020 programme, a process to renew the membership of the joint undertaking was initiated. The aim was to maintain the joint undertaking with a proper balance between airspace users, air navigation service providers, airports, military, professional staff associations and manufacturers, and to offer opportunities to SMEs, academia and research organisations. The selection resulted in the accession of 19 entities, comprising 16 air navigation service providers (from Austria, Croatia, Czechia, France, Germany, Hungary, Ireland, Italy, Lithuania, Norway, Poland, Slovakia, Spain, Sweden, Switzerland and the United Kingdom); six airports (Aéroports de Paris, Avinor, Flughafen München Franz Josef Strauß, Flughafen Zürich-Kloten, Heathrow Airport, Amsterdam Airport Schiphol and Swedavia); nine ATM, avionics and electronic equipment manufacturers (Airtel, Atos, Frequentis, Leonardo, Honeywell International, Indra Systems, Saab, Thales Air Systems and Thales Avionics); two aircraft manufacturers (Airbus and Dassault Aviation) and three research centres (the German Aerospace Center (DLR), the Royal Netherlands Aerospace Centre (NLR) and the Foundation for Industrial and Technical Research (SINTEF)), some of them grouped in consortia.

In addition, 16 associated partners contributed to SESAR 2020. Some of these associate partners were registered in non-EU countries, coming from Australia, Canada, Morocco and the United States. These associate members have been especially relevant in the fields of information and technical services management, network and airport collaboration, airborne systems and communications, CNS systems, support for validations and drone integration. Five of them became SESAR members. As a result, a total of 35 members and associate partners of the joint undertaking, comprising 52 entities, participated in SESAR 2020.

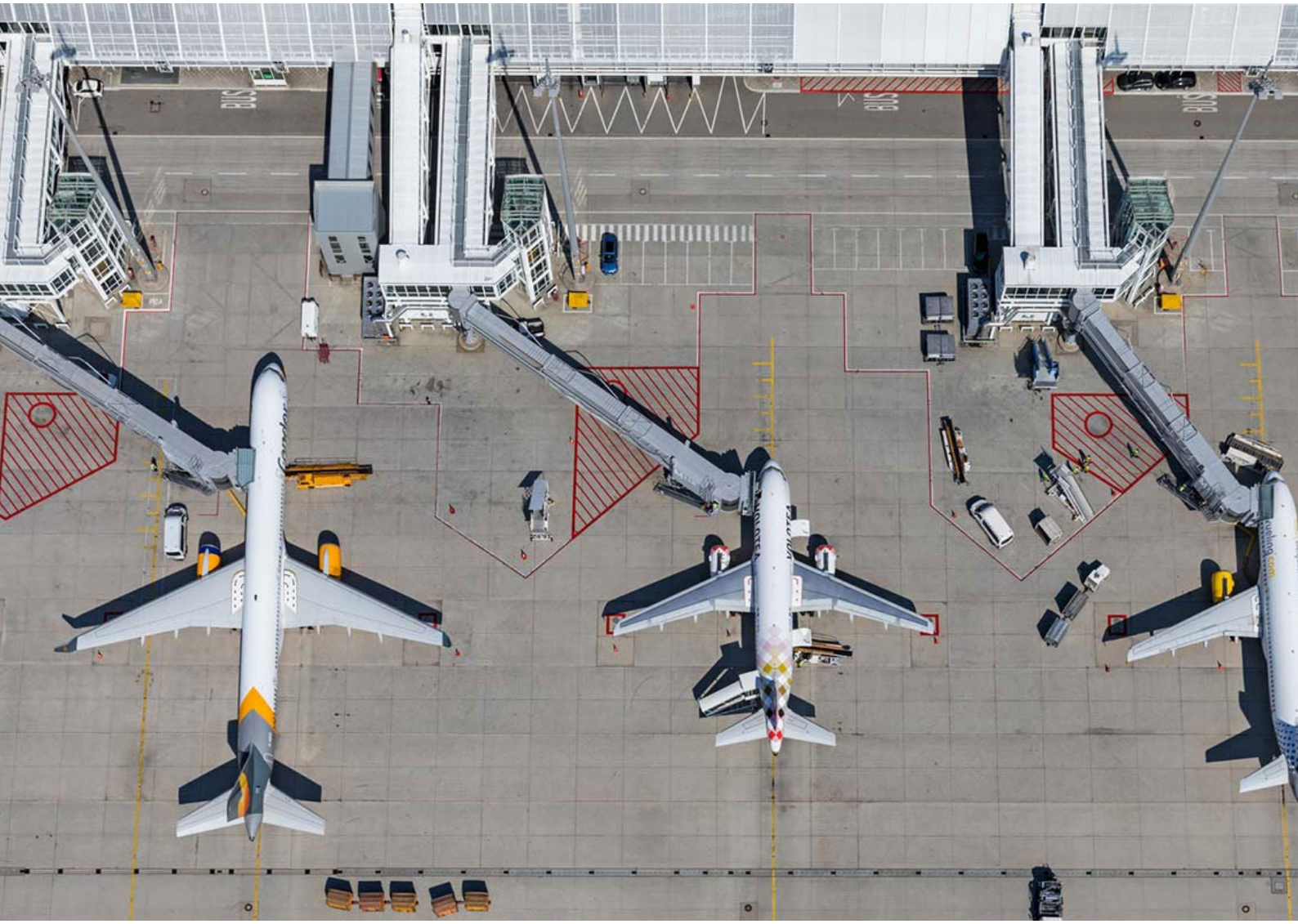
5.1.2 Engaging the wider community

The SESAR 2020 programme received input from other key stakeholders in the aviation sector. In 2017, three civil airspace users' associations representing airlines (International Air Transport Association), business aviation (European Business Aviation Association) and general aviation and rotorcraft users (Aircraft Owners and Pilots Association) signed several framework service contracts to provide advice to the joint undertaking. This continuous interaction allowed civil airspace users in Europe to review and contribute, through their representatives, to many SESAR 2020 deliverables. Also in 2017, the airport community, through the Airports International Council, formalised its engagement with the joint undertaking, providing inputs on behalf of the entire airport community. The professional staff associations also contributed to SESAR 2020. In 2018, five entities, the Air Traffic Controllers' Associations, the European Cockpit Association, the International Federation of Air Traffic Safety Electronics Associations, the European Transport Workers' Federation and the Air Traffic Controllers European Union Coordination formalised framework service contracts with the SESAR JU. The wider military community

participated in SESAR 2020 projects through the military engagement plan for SESAR, allowing military experts to contribute to the updates of the Master Plan and to the review of SESAR 2020 deliverables.

Finally, the SESAR JU maintained close relations throughout SESAR 2020 with national authorities, regulatory bodies and standardisation bodies. Since 2017, several MOCs signed with civil and military national supervisory authorities from 14 Member States and 2 non-EU countries (Iceland and Switzerland) have allowed the review of a number of SESAR 2020 deliverables and have provided valuable input in areas like the need for new or amended regulations, future certification requirements, consideration for future safety, environmental or security cases, and capacity and human factor assessments. In a similar way, the joint undertaking has maintained working arrangements with EASA for mutual benefit since 2009, facilitating, among other things, the alignment of the Master Plan and the European plan for aviation safety. Regarding standardisation bodies, the SESAR 2020 programme also benefited from memoranda of understanding signed with the European Telecommunications Standards Institute and with Eurocae (see Section 2.3.1).

As a result of these engagements, the SESAR 2020 programme benefited during its execution from the input, views and contributions of a very large community of stakeholders representing the many different dimensions of the ATM sector. The outcome of the SESAR 2020 programme has been widely accepted and recognised across the sector as the way forward to a successful evolution of the European ATM system.



6 Lessons learned

The SESAR 2020 programme successfully delivered on its mission to **modernise the European ATM system**, addressing the fragmentation of the EU sky and improving ATM performance in terms of capacity, punctuality, efficiency and environmental footprint.

The benefit of the SESAR 2020 programme goes beyond the 157 funded projects and the 137 delivered technological solutions. In this regard, the SESAR JU has demonstrated that it is far **more than a grant-managing entity**.

The SESAR JU successfully established and maintained the European ATM Master Plan, developed with the active involvement of the entire ATM sector, as the EU roadmap for the development and deployment of the technological innovations that are the backbone of the single European sky. This Master Plan creates a direct link between the SESAR 2020 programme and the EU policy framework, ensuring an optimal **alignment between the operation of the SESAR JU and the EU priorities** and promoting Europe's position on the global stage.

Because national ATM R & I programmes usually address only local issues in a fragmented and often overlapping way, only a collaborative approach at the EU level could have successfully led to the modernisation and harmonisation of the European ATM system and the delivery of the single European sky objectives. The SESAR 2020 programme channelled almost the entirety of the EU ATM R & I efforts into a **portfolio of projects funded under different EU programmes** (Horizon Europe and the Connecting Europe Facility), ensuring cohesion and alignment towards the ambition of the Master Plan, and ultimately of the single European sky initiative. This has resulted in a cumulative impact that is greater than the sum of its parts.

The success of the SESAR 2020 programme demonstrated the relevance of **an integrated public–private partnership**. Over the years, the SESAR JU has successfully created a trusted and collaborative environment where industry companies work together productively during the development phase. This achievement is particularly important in a highly competitive sector such as ATM, in which a few large industry players tend to dominate the market. In addition, by bringing in air navigation service providers, airlines and airports, the SESAR JU has created a customer–supplier dynamic that ensures that research delivers tailored solutions that meet specific needs.

The SESAR 2020 programme confirmed that the SESAR **innovation pipeline** is the most efficient way to identify and mature the most excellent technological innovations from low to high TRL. This is because at the early stages of research, the SESAR 2020 programme adopts a broad topic-oriented approach, aiming at exploring a wide range of possibilities. As projects progress and TRLs increase, the focus becomes more targeted, aligning closely with deployment needs and ultimately leading to practical and deployable solutions.

Moreover, the SESAR JU's approach to R & I emphasises concrete **performance outcomes** from the outset. All 157 projects funded were assigned with specific performance goals deriving from the Master Plan, with results subsequently validated through rigorous evaluation processes (and consolidated in a yearly release exercise). This methodology ensured that research efforts did not only serve knowledge production but also delivered practical applications that contributed meaningfully to the improvement of the performance of the ATM sector. This method led to a significant **acceleration of the time to market and industrialisation** (from TRL 0 to TRL 6) from 10 years under SESAR 1 to 7 years at the end of SESAR 2020.

Finally, the SESAR JU maintained fruitful relations with the EASA and the national aviation authorities during the implementation of the SESAR 2020 programme, which have been key to **facilitating the deployment of the solutions developed**.

At the international level, the SESAR JU contributed to reinforcing the **industrial leadership** of the European aviation sector by supporting concretely the competitiveness of its industry. Moreover, thanks to its intense outreach activities beyond the EU, the SESAR JU has been able to orientate/influence international policy effectively to ensure the harmonisation of

the global ATM system aligned with European standards. This dual achievement has solidified the **SESAR global brand**, which is synonymous across the world with the European innovation leadership in ATM.

The SESAR JU performed all its additional policy and related tasks with only **4.2 % of running costs**, demonstrating its cost-effectiveness. In addition, all partners share the burden of the operating expenses fairly and equitably. This demonstrates the value that all partners place on the programme, reflecting their commitment and belief in its objectives and capacity of action at the systemic level, and their understanding that they experience returns that far exceed their financial investment.

7 References

- Council of the European Union, Council Regulation (EU) No 721/2014 of the Council of 16 June 2014 -amending Regulation (EC) No 219/2007 on the establishment of a Joint Undertaking to develop the new generation European air traffic management system (SESAR) as regards the extension of the Joint Undertaking until 2024, OJ L 192, 1.7.2014, p. 1, ELI: http://data.europa.eu/eli/reg/2014/721/oj.
- Council of the European Union, Council Regulation (EU) 2021/2085 of the Council 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, OJ L 427, 20.11.2021, p. 17, ELI: http://data.europa.eu/eli/reg/2021/2085/oj.
- European Commission, 'A fundamental transport transformation: Commission presents its plan for green, smart and affordable mobility', European Commission website, https://transport.ec.europa.eu/transport-themes/mobility-strategy_en.
- European Commission, Commission Implementing Regulation (EU) No 716/2014 of the Commission of 27 June 2014 on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan, OJ L 190, 28.6.2014, p. 19, ELI: http://data.europa.eu/eli/reg_impl/2014/716/oj.
- European Commission, Commission Implementing Regulation (EU) 2021/116 of the Commission of 1 February 2021 on the establishment of the Common Project One supporting the implementation of the European Air Traffic Management Master Plan provided for in Regulation (EC) No 550/2004 of the European Parliament and of the Council, amending Commission Implementing Regulation (EU) No 409/2013 and repealing Commission Implementing Regulation (EU) No 716/2014, OJ L 36, 2.2.2021, p. 10, ELI: http://data.europa.eu/eli/reg_impl/2021/116/oj.
- SESAR 3 Joint Undertaking, 'Digital SESAR Solutions Catalogue', SESAR Joint Undertaking website, https://www.sesarju.eu/catalogue.
- SESAR 3 Joint Undertaking, 'European ATM Master Plan 2020', SESAR Joint Undertaking website, 17 December 2019, https://www.sesarju.eu/masterplan2020.
- SESAR 3 Joint Undertaking, 'SESAR Deployment Manager', SESAR deployment manager website, https://www.sesardeploymentmanager.eu/.
- SESAR 3 Joint Undertaking, 'U-space Blueprint', SESAR Joint Undertaking website, 9 June 2017, https://www.sesarju.eu/u-space-blueprint.
- SESAR 3 Joint Undertaking, *U-space Concept of Operations (ConOPs): Fourth edition*, Publications Office of the European Union, Luxembourg, 2023, https://data.europa.eu/doi/10.2829/207917.

Follow us
on social media

@ SESAR_JU

SESAR 3 Joint Undertaking

www.youtube.com/SESARJU

Publications Office
of the European Union

PDF ISBN 978-92-9216-213-9 doi:10.2829/298861 MG-02-24-663-EN-N