SESAR 3 Joint Undertaking consolidated annual activity report for 2021

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Abstract

This consolidated annual activity report (CAAR), established in accordance with Article 23 of the financial rules of the SESAR 3 Joint Undertaking, provides comprehensive information on the implementation of the Joint Undertaking's work programme, budget, staff policy plan, management and internal control systems in 2021.

The main focus of this CAAR 2021 are the activities carried out by the SESAR Joint Undertaking (1 January 2021 – 30 November 2021), referenced as SESAR JU. These are assessed against the SESAR JU's relevant legal framework valid at that time. The CAAR 2021 also reports on the activities related to the launch of the Single European ATM Research 3 Joint Undertaking, referenced as the SESAR 3 JU.

The annual activity report will be made publicly available after its approval by the Governing Board.

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Foreword

A catalyst for change

Air traffic is recovering steadily following the pandemic, and all eyes are now focused on a more optimistic future. The successful recovery of the aviation sector will require a concerted effort by all. At the same time, there remain challenges that must urgently be overcome. In particular, there has been a rapid rise in new entrants to the sector, such as drones, and the aviation network needs to continue to reduce emissions and address the lack of scalable capacity. In addition, the aviation sector has to accelerate its transition to a sustainable and digital future, as set out in the EU's sustainable and smart mobility strategy.

As illustrated by this annual activity report, the Single European Sky ATM Research 3 (SESAR 3) Joint Undertaking (JU) is serving as a catalyst for change and the transition towards a green and digital Europe. It will also help make our European industry more competitive and more resilient.

I would like to take this opportunity to thank the SESAR team and all project partners for their continued efforts to deliver innovative solutions through the Horizon 2020 programme. I am very much looking forward to the launch of the new programme this year.

I would also like to acknowledge all of the work that went into the planning and launch of the new SESAR 3 JU. The enlarged membership illustrates the growing will of stakeholders to join forces to help deliver change. Building on the achievements of its predecessor, I am confident that this bigger and bolder partnership will make Europe's aviation infrastructure fit for the digital age via the Digital European Sky programme, while meeting the sector's net zero ambitions.

Henrik Hololei

Director-General of the European Commission's Directorate-General for Mobility and Transport and Chair of the SESAR JU Administrative Board

A new chapter in Air traffic management modernisation

2021 was another challenging year for the JU and its members. The uncertainties and disruptions caused by the pandemic meant once again adjusting our activities where necessary. However, as the pages of this report show, the resolve and commitment of our members remained strong, with progress made in the various research and innovation areas of the programme and towards the targets laid out in the European air traffic management (ATM) Master Plan.

The year was also one of beginnings, with the launch of the SESAR 3 JU within the framework of Horizon Europe, marking a new chapter in modernising European ATM. In addition to having a more diverse membership, the programme of the partnership has been set up in such a way as to both accelerate the innovation life cycle by fast tracking the most promising solutions, and encourage market uptake by pioneers in the industry. I believe that these structural changes to how we innovate should allow greater agility and speed in innovation and, ultimately, in the digital transformation on which we are all banking.

Richard Frizon

Executive Director *ad interim* of the SESAR 3 JU

Executive summary

In 2021, the Single European Sky ATM Research (SESAR) Joint Undertaking (JU) [1] members continued to face turbulent times due to the ongoing pandemic and the increasing pressure to address the environmental footprint of the sector. Despite this extremely challenging context, the SESAR JU made considerable progress in delivering the research and innovation (R&I) activities of the SESAR 2020 programme ([2]), while at the same time launching the new SESAR 3 JU partnership and making preparations for a programme of R&I. The activities highlighted in this report illustrate the JU's contribution to the European Commission's strategic priorities, notably the European Green Deal and the goals of building a Europe fit for the digital age and a stronger Europe in the world.

Delivering solutions

The SESAR JU members and partners were successful in advancing new technologies and procedures through the SESAR innovation pipeline release process, in accordance with the timeline set by the European air traffic management (ATM) Master Plan – Europe's roadmap for the digital transformation of ATM. In September, the JU published the fourth edition of the *SESAR Solutions Catalogue*, which charts progress in developing the technological and procedural solutions needed for delivering the Digital European Sky. The catalogue contains 101 delivered solutions (that reached the required level of maturity for industrialisation) addressing key areas of the ATM value chain, notably airport operations, air traffic services (ATSs), network operations and the enabling infrastructure. As many as two thirds of the solutions delivered are now part of deployment plans at local and European levels, meeting business needs and resulting in tangible benefits in terms of performance. The catalogue also presents details of the ongoing R&I within 80 candidate solutions in the SESAR 2020 programme and the progress made towards the vision of the Digital European Sky programme. Altogether, these innovative concepts and solutions are contributing to the drive to futureproof Europe's aviation infrastructure, in line with building a Europe fit for a digital age.

Feeding the SESAR innovation pipeline

Recognising the ongoing effects of the COVID-19 crisis on the sector, the JU implemented a number of measures, including extending the duration of grants where necessary, to allow projects to conclude their validation activities and deliver the technical outcomes in accordance with the timelines of the European ATM Master Plan.

In total, the JU continued to manage and monitor the progress of 71 projects across its three strands of research in 2021, namely exploratory research, industrial research and validation, and very large-scale demonstrations. These projects represent about 300 different beneficiaries, of which nearly 20 %

([1]) The SESAR JU ceased to exist on 30 November 2021 following the entry into force of the single basic act (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). In accordance with Article 174(9) of this regulation, the SESAR 3 JU became 'the legal and universal successor in respect of all contracts, including employment contracts and grant agreements, liabilities and acquired property of the SESAR JU …, which shall replace and succeed'.

([2]) Also referred to as the SESAR 2020 innovation R&I programme or the SESAR 2020 R&I programme, SESAR 2020 refers to the coordinated set of activities described in this document that are being undertaken by SESAR JU members and managed by the SESAR JU.

are small and medium-sized enterprises, 17 % are higher education organisations or universities, and 9 % are research organisations.

The projects addressed a wide variety of topics that are key to increasing the resilience of the system, enabling scalability and enhancing safety. These include artificial intelligence tools to enable greater levels of automation, solutions to support intermodality, dynamic airspace configuration, flight-centric operations, virtual centres (e.g. the delegation of ATSs), collision avoidance and future satellite technologies, including 5G. Considering the urgency of addressing the climate impact of aviation, many of the projects are focused on leveraging digital technology in order to support a swift transition to greener aviation, in line with Europe's Green Deal. These include projects investigating climate mitigation solutions and a large-scale demonstration aimed at accelerating the implementation of existing fuel-efficient solutions across all phases of flight.

In September, the European Climate, Infrastructure and Environment Executive Agency (CINEA) launched a new call under the Connecting Europe Facility (CEF) containing provisions for a series of pilot Digital European Sky Demonstrators in the areas of green aviation and urban air mobility. As indicated in the Multiannual Work Programme and in the Bi-Annual Work Programme for years 2022-2023, an indicative budget of up to EUR 60 million is foreseen for the demonstrators, which will run from 2022 to 2025 within the framework of the SESAR 3 JU.

Awarding the best in class

The progress made by the projects was celebrated in June through the 2021 Digital European Sky Awards, which recognised the best of R&I in ATM in Europe. The five winning projects were selected from a shortlist, following rigorous evaluation by a distinguished jury of SESAR JU members and partners and a public vote. Projects within the exploratory research portfolio had a further opportunity to increase the visibility of their work during the SESAR Innovation Days in December. Altogether, this conference featured more than 30 posters and 30 papers, covering wake vortex detection, data-driven methods for safety and resilience prediction, climate-optimised trajectories, capacity-sharing in virtual centres and drone traffic management, among other research topics.

Advancing learning and sharing knowledge

In 2021, the SESAR JU organised a series of technical webinars aiming to provide an overview of SESAR 2020 achievements and a flavour of the concrete benefits that ATM modernisation is starting to bring to the entire aviation ecosystem. The webinars also explored what still needs to be done and, in particular, how technology can bring about fundamental changes to the way that we manage air traffic in European airspace. A total of five webinars, with an average of 550 participants, were held throughout the course of 2021, reaching a total global audience of over 3 000 participants. The webinar format made the content of the SESAR 2020 programme accessible to the European public in a way that had never been possible before.

Changes in leadership

In July 2021, Florian Guillermet stepped down from his role as Executive Director of the JU to take up a new position as CEO of Direction des Services de la Navigation Aérienne (DSNA), France's air navigation services provider. The departure of Florian Guillermet led to a decision by the Administrative Board of the JU to appoint Richard Frizon as its interim Executive Director, to ensure the smooth and effective continuation of the work of the JU, until a new Executive Director is appointed in 2022.

Preparations and launch of the SESAR 3 Joint Undertaking

In 2021, the SESAR JU made preparations for the launch of the SESAR 3 JU, which started operations on 30 November. This included the transfer of all of the administrative and legal elements necessary to allow the corporate, financial and administrative management of the SESAR 3 JU. Furthermore, the SESAR JU provided support to the European Commission in reviewing and providing feedback on key documents applicable for 2021–2031, such as the single basic act ([3]), the model grant agreement and members' letters of commitment. On the programme side, the SESAR JU prepared a multiannual work programme, with a view to agreeing on the content and overall framework of activities to be carried out by the SESAR 3 JU from 2021 to 2031. On 14 December 2021, the first meeting of the Governing Board of the SESAR 3 JU was held, marking the official launch of the new partnership.

([3]) 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.

Introduction

Factsheet

Table 1: The SESAR Joint Undertaking in 2021 in brief

Name	Single European Sky ATM Research Joint Undertaking (SESAR JU)
Objectives	The SESAR JU is responsible for coordinating, rationalising and concentrating all relevant air traffic management (ATM) research and innovation (R&I) efforts in the EU, with the aim of contributing to the modernisation and harmonisation of ATM in Europe
Founding legal act	Established under Council Regulation (EC) No 219/2007 of 27 February 2007 (the SESAR JU basic act) ([4]) Modified by Council Regulation (EC) No 1361/2008 (the SESAR JU regulation) ([5]) Last amended by Council Regulation (EU) No 721/2014 ([6])
Executive Director	Florian Guillermet (until 4 July 2021)
Executive Director *ad interim*	Richard Frizon (from 5 July 2021)
Administrative Board ([7])	1. SESAR JU members (members with voting rights): • European Union (founding member) • EUROCONTROL (founding member) • **Airbus** • **AT-One consortium** • **B4-consortium** • **COOPANS consortium** • **Dassault Aviation** • **Deutsche** Flugsicherung **(DFS)** • Direction des Services de la Navigation Aérienne (**DSNA)** • **ENAIRE** • **ENAV** • **Frequentis consortium** • **Honeywell** • **Indra**

([4]) Council Regulation (EC) No 219/2007 of 27 February 2007 on the establishment of a Joint Undertaking to develop the new generation European air traffic management system (SESAR).
([5]) Council Regulation (EC) No 1361/2008 of 16 December 2008 amending Regulation (EC) No 219/2007 on the establishment of a joint undertaking to develop the new generation European air traffic management system (SESAR).
([6]) Council Regulation (EU) No 721/2014 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.
([7]) Composition as of 30 November 2021.

	• **Leonardo** • **NATS** • **North European ATM Industry Group (NATMIG)** • **SESAR European Airports Consortium (SEAC) 2020** • **Skyguide** • **Thales AVS France SAS** • **Thales LAS France SAS** 2. Representatives at European level of civil users of airspace (members without voting rights): • **the military** • **air navigation service providers (ANSPs)** • **equipment manufacturers** • **airports** • **staff in the ATM sector** • **the scientific community**
Other governance bodies	The Programme Committee The Scientific Committee The Master Planning Committee
Strategic research agenda	SESAR 2020 multiannual work programme, adopted by the SESAR JU Administrative Board in 2015 ([8])

Table 2: The SESAR 3 Joint Undertaking in 2021 in brief

Name	Single European Sky ATM Research 3 Joint Undertaking (SESAR 3 JU)
Objectives	The mission statement of the SESAR 3 JU is to accelerate through R&I 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 the time to market through focused and agile R&I, supporting faster transitions to deployment through an extended innovation life cycle.
Founding legal act	Established under Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the Joint Undertakings under Horizon Europe and repealing Regulations (EC)

([8]) Decision ADB(D)05-2015 set out the adoption of the SESAR 2020 multiannual work programme.

	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 (the single basic act)
Executive Director *ad interim*	Richard Frizon
Governing Board ([9])	1. SESAR 3 JU founding members (members with voting rights): • Administratia Romana a Serviciilor de Trafic Aerian (ROMATSA) • Aena • Aeroport de Paris • Aeroporti di Roma • Airbus SAS • Air France • Air Navigation Services Czech Republic (ANS CR) • Airtel ATN Lt • Alliance for New Mobility Europe (AME) • Athens International Airport • Austro Control • Boeing Aerospace Spain • Brussels Airport Company • Bulatsa • Centro Italiano Ricerche Aerospaziali (CIRA) • Collins Aerospace Ireland Limited • Croatia Control • Deutsche Lufthansa AG • Deutsches Zentrum für Luft- und Raumfahrt (DLR) • DFS • Drone Alliance Europe • DSNA • Easyjet Europe Airline Gmbh • Ecole Nationale de l'Aviation Civile (ENAC) • ENAIRE • ENAV • EU • EUROCONTROL • Flughafen München

([9]) Composition as of 31 December 2021.

	• Frequentis • Honeywell • Hungaro Control • Indra • Irish Aviation Authority • Københavns Lufthavne (Copenhagen Airports A/S) • Leonardo • LFV • Luchtverkeersleiding Nederland (LVNL) • Naviair • NAV Portugal • NLR • ONERA • Pipistrel • Polska Agencja Żeglugi Powietrznej (PANSA) • Prague Airport • Ryanair • Saab • Safran • Schiphol • SEA • SINTEF • Swedavia • Thales LAS France SAS • Volocopter • VTT 2. Observers with voting rights: ([10]) • **civil users of airspace** 3. Observers without voting rights: • **European Defence Agency (EDA)** • **ANSPs (CANSO)** • **equipment manufacturers (ASD)** • **airports (Airports Council International (ACI))**

([10]) Article 150(3) of the single basic act.

	• **staff associations** • **the scientific community** • **European Union Aviation Safety Agency (EASA)** • **European Organisation for Civil Aviation Equipment (EUROCAE)** • **the unmanned air vehicle industry**
Advisory bodies ([11])	The States' Representative Group The Scientific Committee
Strategic research agenda	Strategic research and innovation agenda for the digital European sky

About the SESAR 3 Joint Undertaking

The SESAR JU was created under Article 171 of the Treaty Establishing the European Community and confirmed under Article 187 of the Treaty on the Functioning of the European Union to provide an effective coordination role for all relevant research and development efforts within the EU. Its mandate and mission are coherent with the high-level goals of the single European sky initiative.

Founded by the EU and EUROCONTROL, the SESAR JU was established in 2007 as a joint undertaking ([12]) and became an EU body in 2009. It was subsequently augmented by 15 stakeholder members and then, in 2016, by a further four members, all committed to achieving the mission of the agency by 2024. Together with their partners and affiliates, the SESAR JU members other than the EU represent over 120 organisations from across the ATM community, including civil and military ANSPs, airports, civil and military airspace users, staff associations, academic institutions and research centres. Through these partnerships and further collaboration with staff associations, regulators and the larger scientific community, the SESAR JU unites the skills of over 3 000 experts to fast track and focus research leading to change in European ATM.

In 2019, the European Commission launched activities to determine options for an integrated ATM partnership (SESAR 3) in the next multiannual financial framework (2021–2027). The European Commission published a legislative proposal in February 2021, which led to a new Council regulation adopted on 19 November 2021, which entered into force on 30 November 2021. In accordance with Article 174(9) of this regulation, the SESAR 3 JU became 'the legal and universal successor in respect of all contracts, including employment contracts and grant agreements, liabilities and acquired property of the SESAR JU …, which it shall replace and succeed'.

Consolidated annual activity report for 2021

This consolidated annual activity report (CAAR) is in accordance with Article 23 of the partnership's financial rules ([13]). In addition, it mirrors the structure of the biannual work programme for 2022–2023.

([11]) Articles 153 and 154 of the single basic act.

([12]) The SESAR JU was established under Council Regulation (EC) 219/2007 of 27 February 2007 (as modified by Council Regulation (EC) 1361/2008 (the SESAR JU regulation) and last amended by Council Regulation (EU) 721/2014).

([13]) Regulation (EU, Euratom) No 2018/1046 of 18 July 2018 of the European Parliament and of the Council on the Financial Rules applicable to the general budget of the Union, amending Regulations (EU) No 1296/2013, (EU) No 1301/2013,

The type of content provided remains, only the structure has been modified to adapt it to the new framework. Although the structure is different, the CAAR for 2021 effectively reports against the objectives defined in the SESAR JU single programming document (SPD) for 2021–2023 ([14]).

The main focus of this CAAR for 2021 is the activities carried out by the SESAR JU from 1 January to 30 November. The 2021 CAAR also reports on the activities related to the launch of the SESAR 3 JU. These are assessed against the SESAR JU's relevant legal framework valid at that time.

This CAAR has several purposes:

- it provides evidence of the progress made towards achieving the SESAR JU's key objectives as defined in the 2021–2023 SPD implementing the SESAR 2020 multiannual work programme ([15]), taking into account resources used during the reporting period;
- it describes the preparatory work and the transition phase for the establishment of the SESAR 3 JU (see Section I.3);
- it outlines the management and oversight systems in place at the SESAR JU, including reference to the European Commission's internal control framework;
- it includes a declaration of assurance (Chapter VI) in which the Executive Director, in his role as authorising officer, provides reasonable assurance regarding the true and fair view given by the report and pertaining to the legality and regularity and the sound financial management of all transactions under his responsibility, and provides reasonable assurance that resources assigned to the activities reported on in the CAAR have been used for their intended purpose and in accordance with the principle of sound financial management.

Chapter I of the CAAR first highlights progress and presents the cumulative achievements of the SESAR JU since 2014. It then describes the transition towards the establishment of the SESAR 3 JU. Finally, it presents the operational achievements of 2021 in relation to the annual objectives identified in the SPD for 2021–2023. Chapter II of the CAAR presents the achievements of 2021 in relation to the annual objectives identified in the SPD for 2021–2023 in the area 'support to operations'. Chapter III of the CAAR outlines the objectives and presents the activities carried out by the governance of the SESAR JU. Chapter IV outlines the achievements of 2021 in relation to the SESAR JU internal control framework. Finally, Chapter V is dedicated to management assurance and includes the Governing Board's assessment and the review of the elements supporting the assurance.

All of the objectives related to the abovementioned domains were achieved in 2021.

(EU) No 1303/2013, (EU) No 1304/2013, (EU) No 1309/2013, (EU) No 1316/2013, (EU) No 223/2014 and (EU) No 283/2014 and Decision No 541/2014/EU and repealing Regulation (EU, Euratom) No 966/2012 (OJ L 193, 30.7.2018, p. 1).

([14]) The SPD for 2021–2023 is available online.

([15]) The multiannual work programme, which was approved by the Administrative Board in 2015, is updated through SPDs established each year.

1 Implementation of the annual work programme for 2021 (operations)

1.1 Research and innovation activities (2015–2021)

The Single European Sky ATM Research (SESAR) Joint Undertaking (JU) is the technological pillar of the EU's single European sky (SES) policy and a key enabler of the European Commission's sustainable and smart mobility strategy. SESAR defines, develops and deploys technologies to transform air traffic management (ATM) in Europe.

The activities of the SESAR 2020 programme are funded through four different funding instruments. The Horizon 2020 framework programme for research and innovation (R&I) (H2020) provided EUR 585 million, and the Connecting Europe Facility (CEF) provided EUR 10 million specifically for drone U-space ([16]) demonstration activities. In addition, two initiatives were funded by assigned revenue (revenue used to finance specific items of expenditure), one to the value of EUR 500 000 and another to the value of EUR 800 000. This amounts to total funding from the EU of EUR 596.3 million. The SESAR JU maintains full compliance with these frameworks ([17]).

The results of ATM R&I activities are transferred in the form of SESAR Solutions ([18]), resulting in these solutions being made available for deployment and thereby making a positive contribution towards the achievement of the SES. The EU aviation strategy, the SES objectives, the ATM Master Plan (setting out how medium- and long-term objectives can be achieved) and the R&I activities that ultimately lead to the delivery and the transfer for deployment of SESAR solutions together make up the SESAR innovation pipeline.

([16]) U-space refers to a set of new services relying on a high level of digitalisation and automation of functions, and specific procedures designed to support safe, efficient and secure access to airspace for a large numbers of drones, with an initial look at very low-level operations.

([17]) Besides the EU contribution of EUR 585 million established under H2020, an additional EU contribution of EUR 11.3 million was provided to the SESAR JU by the European Commission under three delegation agreements through which the SESAR JU was mandated to carry out additional activities in the area of ATM, namely:

1. delegation agreement EC/SESAR JU (reference: MOVE/E3/DA/2016-669/SI2.743803) signed on 6 December 2016, with a delegated budget of EUR 500 000 in assigned revenue to organise a call for proposals for a geofencing demonstration, in accordance with Articles 54(2)(a) and 58(1)(c)(iv) of 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 (OJ L 193, 30.7.2018, p. 1) (the EU financial regulation);
2. delegation agreement EC/SESAR JU (reference: MOVE/E3/DA/2017-477/SI2.766828) signed on 10 November 2017, with a delegated budget of EUR 800 000 in assigned revenue to procure a study to develop a proposal for the future architecture of European airspace;
3. delegation agreement EC/SESAR JU (reference: MOVE/E3/DA/2017-564/si2.771010) signed on 13 December 2016, with a delegated budget of EUR 10 million in assigned revenue from the CEF funds to organise a call for proposals on U-space demonstrations.

([18]) SESAR solutions are referred to as 'candidate SESAR solutions' as long as they are under development in the industrial research phase of the SESAR innovation pipeline. Once validated at the V3 level of maturity, they are packaged and referred to as 'SESAR solutions'.

1.1.1 Innovation pipeline in practice (2015–2021)

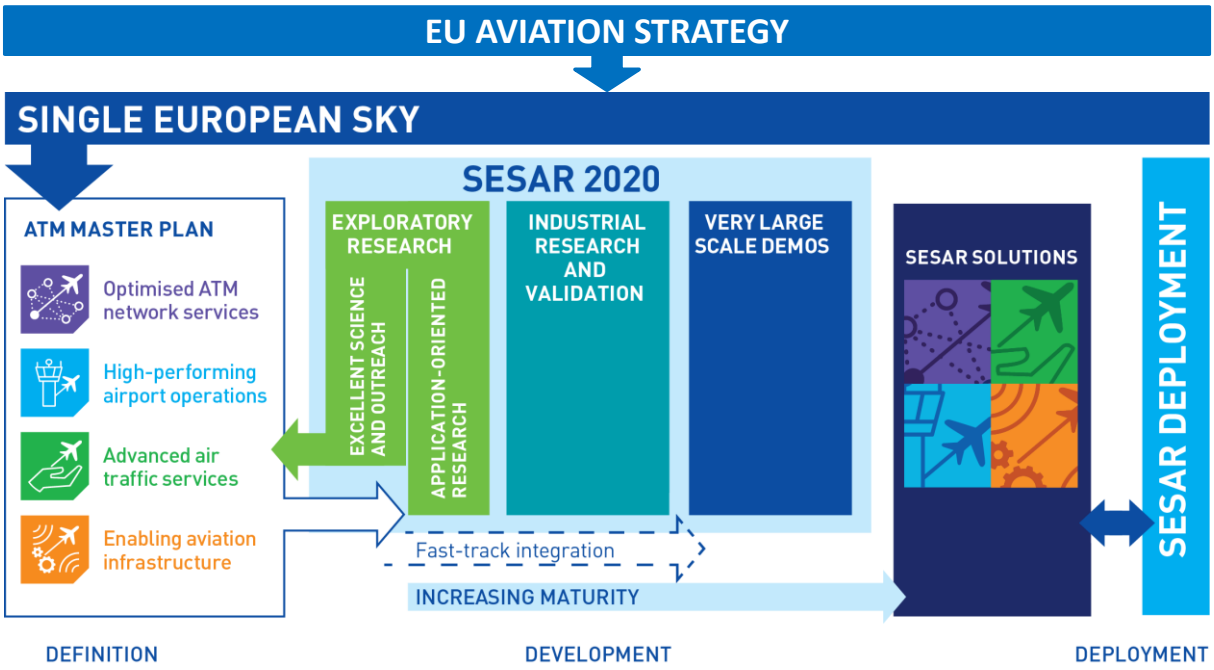


Figure 1: The SESAR Innovation Pipeline – from the EU aviation strategy to SESAR Solutions

As shown in Figure 1, the SESAR innovation pipeline starts with the EU aviation strategy and the SES objectives (which feed into the European ATM Master Plan, the main planning tool that defines the ATM modernisation roadmap and priorities that are maintained and updated on a regular basis). Operational and technology solutions then pass through three R&I phases, maturing as they pass along the pipeline. The level of maturity of research outcomes is assessed using the European operational concept validation methodology (EOCVM), a well-established control and monitoring process linked to technology readiness levels (TRLs).

- **Exploratory research (ER)** addresses both transversal topics for future ATM evolution and application-oriented research. ER covers research activities up to TRL2 ([19]). This phase of research also includes the work of SESAR's knowledge transfer network (KTN), whose aim is to facilitate the development of ATM research in Europe in support of the SESAR JU. ER is wholly funded by the EU and is fully compliant with H2020 and its rules for participation ([20]).
- **Industrial research (IR)** includes applied research, pre-industrial development and validation projects, and results in the development of SESAR Solutions. Annual releases of these technologies are assessed for maturity and potential benefit. IR covers research activities up to maturity level V3/TRL6.
- **Very large-scale demonstration (VLD)** activities are demonstrations of SESAR Solutions or of particular elements of a programme concept. These demonstration activities act as a bridge between the development and deployment phases of SESAR. They are funded by H2020 or the

([19]) As required by H2020, the maturity of research outcomes is assessed using the TRL model, combined with the EOCVM model for the assessment of technological and operational concept development.

([20]) Regulation (EU) No 1290/2013 of the European Parliament and of the Council of 11 December 2013 laying down the rules for participation and dissemination in 'Horizon 2020 – the Framework Programme for research and Innovation (2014-2020)' and repealing Regulation (EC) No 1906/2006 (OJ L 347, 20.12.2013, p. 81).

CEF (drone U-space demonstration activities) or, in the case of work undertaken by SESAR JU members other than the EU, by assigned revenue (through restricted calls), but also by open calls to ensure participation by a range of stakeholders beyond SESAR JU members, including small and medium-sized enterprises (SMEs) and new entrants.

Provided a cost–benefit analysis (CBA) returns a positive result, SESAR solutions whose level of maturity is assessed to be V3/TRL6 pass to the stage of deployment, in the form of either common projects or other types of deployment activities (e.g. at national level).

The Sections I.1.1.1–I.1.1.3 provide an overview of the cumulative achievements in each of the three successive phases of R&I (ER, IR and VLDs) since the beginning of the SESAR 2020 programme.

1.1.1.1 Delivery of exploratory research

The SESAR JU delivers ER results (both fundamental research and ATM application-oriented research) through 86 projects that either are in execution or have already been closed resulting from the following calls for proposals under the H2020 framework.

- The first ER call (ER1), with reference H2020-SESAR-2015-1, resulted in 28 projects aiming to produce tangible results in the fields of ATM excellent science and outreach and ATM application-oriented research. The outcomes of 11 of these projects were incorporated into the specifications of the call for proposals for the next wave of projects in the second R&I phase, IR projects (referred to as the wave 2 call; see Section I.1.1.2), showing the effectiveness of the SESAR innovation pipeline. These projects are all closed and not addressed in this document.
- The second ER call (ER2), focusing on remotely piloted aircraft systems (RPASs), with reference H2020-SESAR-2016-1, resulted in nine projects that addressed a wide variety of topics, including the concept of operations (ConOps) for drone operations, critical communications, surveillance and tracking, information management, aircraft systems, ground-based technologies, cyber-resilience and geofencing. These projects are all closed and not addressed in this document ([21]).
- The third ER call, coupled with the first open VLD call (ER3-VLD1 open), with reference H2020-SESAR-2016-2, resulted in eight projects addressing new metrics to capture network effects, a new methodology and guided approach for fast-time simulation, advanced prediction models for flexible trajectory-based operations (TBOs), and measures to manage global navigation satellite system (GNSS) threats (e.g. jamming and spoofing). One project (ENGAGE) assumed the role of the SESAR 2020 KTN and is in execution until June 2022 (more information on this project can be found in Section I.4.1.1).
- The fourth ER call (ER4), with reference H2020-SESAR-2019-2, was launched in 2019. After completion of the call procedure and the successful awarding of grants, 29 ER projects entered the grant agreement preparation phase, which was completed at the beginning of 2020. As a second outcome of the call procedure, the SESAR JU established a reserve list of 12 proposals, which were then awarded a grant as a result of the allocation of additional budget. The preparation and signing of grant agreements were finalised during 2020. The delivery of outcomes is expected by 2022. Information about the 41 projects financed through this call can be found in Section I.4.2.

Other activities related to ER carried out during 2020 were intended to foster innovation and advanced technology in ATM. In particular, SESAR Innovation Days were held in various EU Member States to

([21]) Detailed information on the projects funded through ER1 and ER2 can be found in previous consolidated annual activity reports of the SESAR JU.

support dissemination of project results throughout the research community, while the Young Scientist Award, which again took place in 2020, recognises young scientists with the potential to contribute to scientific research in the field of ATM. Finally, 2020 saw the ramping up of the SESAR Digital Academy initiative, which was launched in 2019 to bring together, under one umbrella, access to SESAR ER 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. More information on these events can be found in Section II.1.2.

Taken together, ER projects funded by the SESAR 2020 programme benefited 280 different organisations, of which 35 % were higher education organisations or research centres from all over Europe.

1.1.1.2 Delivery of industrial research

A robust delivery process

The SESAR JU release process enables members and partners to carry out research in stages and at each stage to validate SESAR candidate solutions in real-life operational environments. Thus, the SESAR JU, with validation sites across Europe, has taken R&I out of the laboratory and connected it to the real world.

A total of 123 SESAR candidate solutions were developed and validated as part of the IR activities carried out under the projects of wave 1 (call reference H2020-SESAR-2015-2) and wave 2 (call reference H2020-SESAR-2015-2). Activities carried out in these projects covered the four key features of the ATM master plan, namely optimised ATM network services, high-performing airport operations, advanced air traffic services (ATSs) and enabling aviation infrastructure.

Through the release process, SESAR candidate solutions are validated at a certain maturity level: V1 (or TRL2), V2 (or TRL4) or V3 (or TRL6), the last of which corresponds to readiness for industrialisation and further deployment. Releases are delivered every year. Figure 2 shows the number of (candidate) SESAR solutions delivered through releases since the launch of the SESAR 2020 programme: release 7, during the ramp-up of the programme; release 8 (which concluded in April 2019); release 9 (which started in 2019 and concluded in April 2020); and release 10 (which started in 2020 and concluded in April 2021) ([22]).

([22]) Release 11 activities started in 2021 and will be concluded in April 2022. More information about release 11 activities is available in Section I.4.3.3.2.

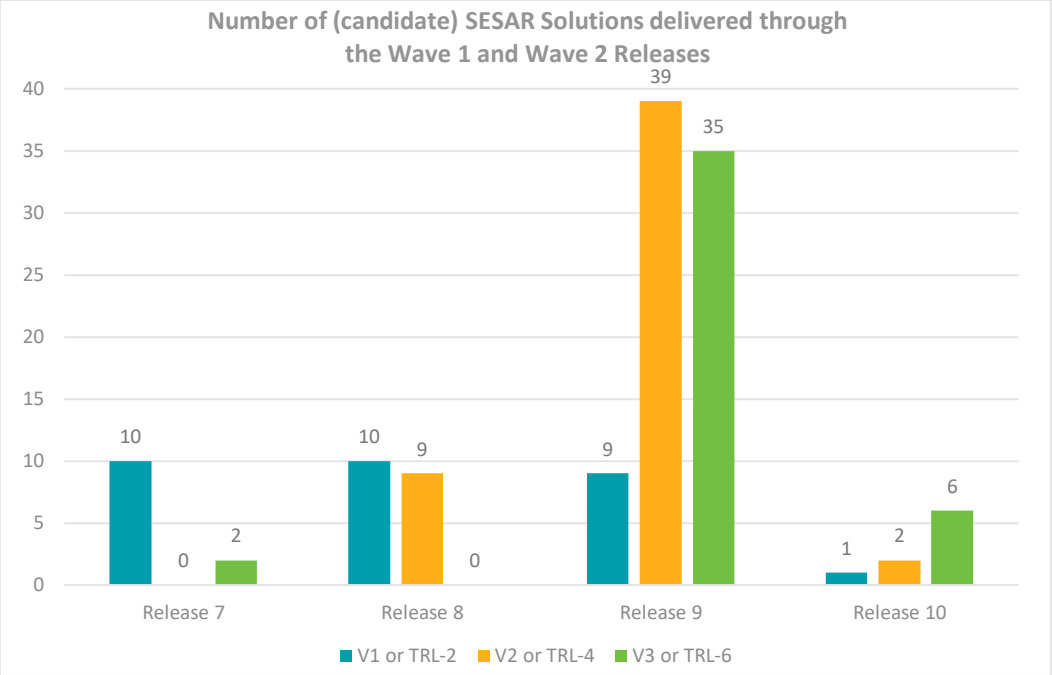


Figure 2: Number of (candidate) SESAR Solutions delivered through releases 7, 8, 9 and 10 (at the end of 2021)

Figure 3 summarises the numbers of (candidate) SESAR solutions delivered in releases 7–10 of waves 1 and 2 that reached each maturity level, categorised by the key feature of the ATM Master Plan addressed by the projects.

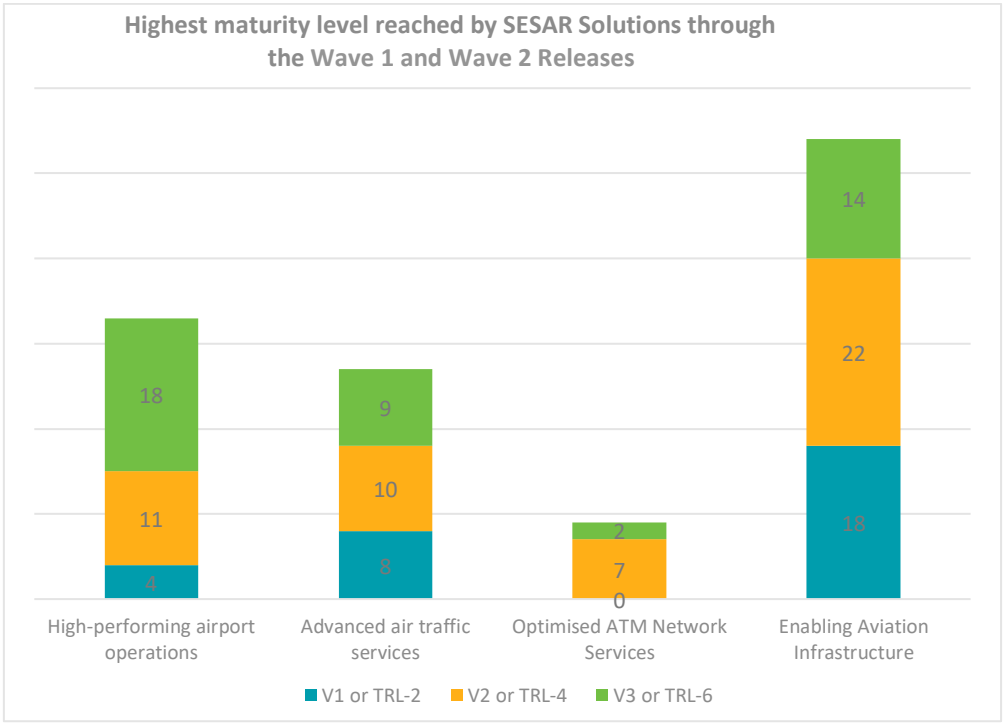


Figure 3: Cumulated number of (candidate) SESAR Solutions delivered through releases 7, 8, 9 and 10 per key feature (at the end of 2021)

In wave 1, in total EUR 202.7 million was awarded in funding to 125 beneficiary organisations, of which 39 were SESAR JU members, either in their own right or as part of a consortium ([23]), 80 were linked third parties and nine were SMEs.

In 2021, the SESAR JU continued the management of the IR-VLD wave 2 call for proposals, which was launched in early 2019 and identified both candidate solutions warranting further development and the next set of candidate solutions that it is hoped, by the end of 2022, will complement the performance gains already provided by the SESAR 2020 programme. The wave 2 call resulted in the award of funding to 12 IR projects.

In addition, in 2021, the SESAR JU managed three additional IR projects funded through a final call for proposals for IR projects, IR-VLD wave 3, using funds remaining from the amount set aside for wave 1 projects.

More information on the wave 2 and wave 3 projects can be found in Sections I.4.3.1 and I.4.3.2.

Two additional projects (PJ19 W2 and PJ20 W2) focused on transversal steering activities, namely the maintenance of the ATM Master Plan, the management of system engineering requirements and content integration (e.g. consolidation of the performance results). More information on these projects is available in Section I.4.1.1.

Meeting the performance ambition established in the European ATM Master Plan

The SESAR JU, in addition to implementing a development and validation process for SESAR candidate solutions, has designed a performance management process to measure the performance of validation activities against the ambitions recorded in the European ATM Master Plan, which are translated into key performance areas (KPAs) and related measurable indicators.

The SESAR 2020 programme has already made an effective contribution to the performance targets set out in the European ATM Master Plan. Figure 4 depicts diagrammatically the expected contribution of SESAR 1 and SESAR 2020 wave 1 solutions in each of the KPAs of the ATM Master Plan. Achieving these expected contributions will require solutions to be deployed in an optimal and timely manner.

([23]) In addition to EUROCONTROL (founding member), there are a further 19 stakeholder organisations, some of which are consortia.

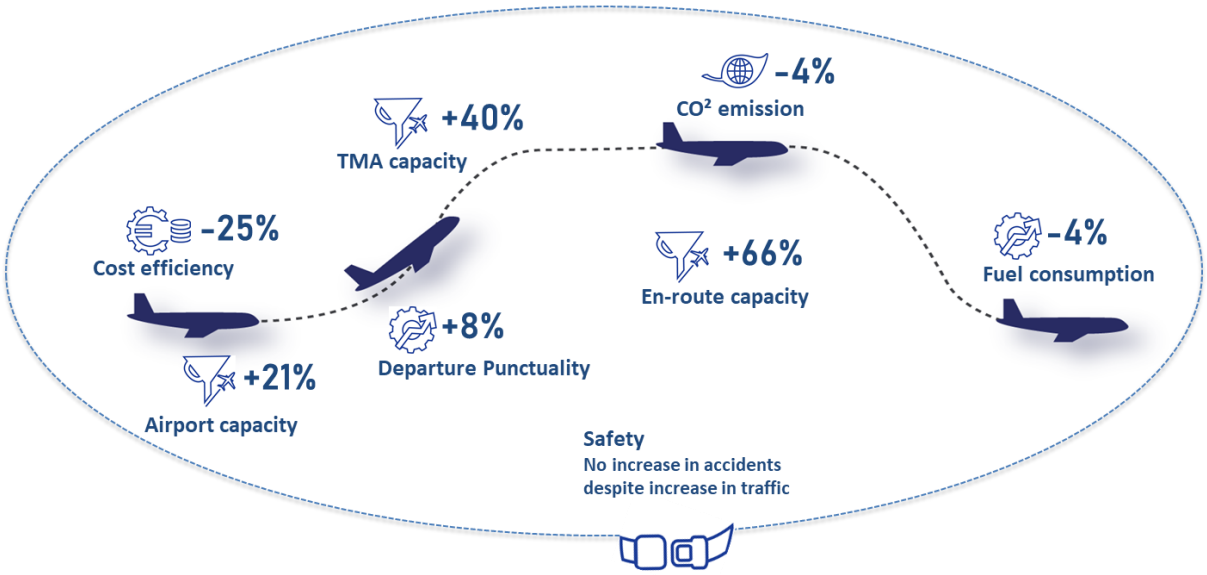


Figure 4: Contribution of SESAR 1 and SESAR 2020 wave 1 candidate solutions to the achievement of the performance ambitions set out in the European ATM Master Plan

NB: TMA, terminal manoeuvring area.

1.1.1.3 Delivery of very large-scale demonstration activities

VLD projects aim to demonstrate SESAR Solutions in close-to-operational environments involving a broad range of ATM stakeholders. These projects aim to confirm the benefits of SESAR Solutions and increase awareness of promising solutions among a broader group of airspace users (AUs) and other aviation end users and ultimately:

- generate further confidence to support buy-in from the main stakeholders, including regulators for future deployments;
- significantly reduce the business risks for both operational stakeholders and industry;
- provide further inputs to related standardisation activities;
- raise awareness regarding SESAR activities related to ATM performance issues and their results;
- accompany SESAR pioneers all the way to pre-deployment;
- assess full-scale deployment readiness.

Within SESAR 2020, 28 VLD projects that are in execution or have already been closed resulted from the following calls for proposals under the H2020 framework:

- IR-VLD wave 1 (with reference H2020-SESAR-2015-2). The five VLDs covered the four key features of the ATM Master Plan, focusing mainly on the flight trajectory profile generated by the flight management system downlinked to and used by the ATM ground systems, the integration of airport solutions for optimising the platform operations, cross-border application of the extended terminal manoeuvring area (TMA) operations and extended network collaborative management. These projects are all closed and not addressed in this document.
- VLD open all (with reference H2020-SESAR-2016-2). This call was launched at the end of 2016 and covered solutions enabling high-performing aviation in Europe, global interoperability, and the safe integration of all air vehicles. The call resulted in the award and signature of 10 grants,

with a focus on demonstrating SESAR Solutions for high-performing aviation in Europe, global interoperability and safe integration of all air vehicles. One project, AUDIO, completed its activities and was closed in 2021. More information can be found in Section I.4.4.1.1.

- IR-VLD wave 2 (with reference H2020-SESAR-2019-1). The call resulted in the award of funding to three VLD projects. In addition, in 2020, the SESAR JU prepared and launched two last calls for proposals covering VLDs. More information can be found in Section I.4.4.1.2.
- Open VLD2 (with reference H2020-SESAR-2020-1). The call financed eight VLDs in total and was defined using the priorities set out in the European ATM Master Plan, and in particular in the essential operational changes set out in the 2020 edition of the European ATM Master Plan. More information can be found in Section I.4.4.1.3.
- Wave 3 (with reference H2020-SESAR-2020-2). The call financed two VLDs using funds made available from the final amount of the wave 1 projects. More information can be found in Section I.4.4.1.4.

1.1.2 Overview of calls and grants up to 2021

SESAR programme (2015–2021)

The SESAR 2020 programme has funded projects in each phase of the SESAR innovation pipeline through 10 calls for proposals (Figure 5).

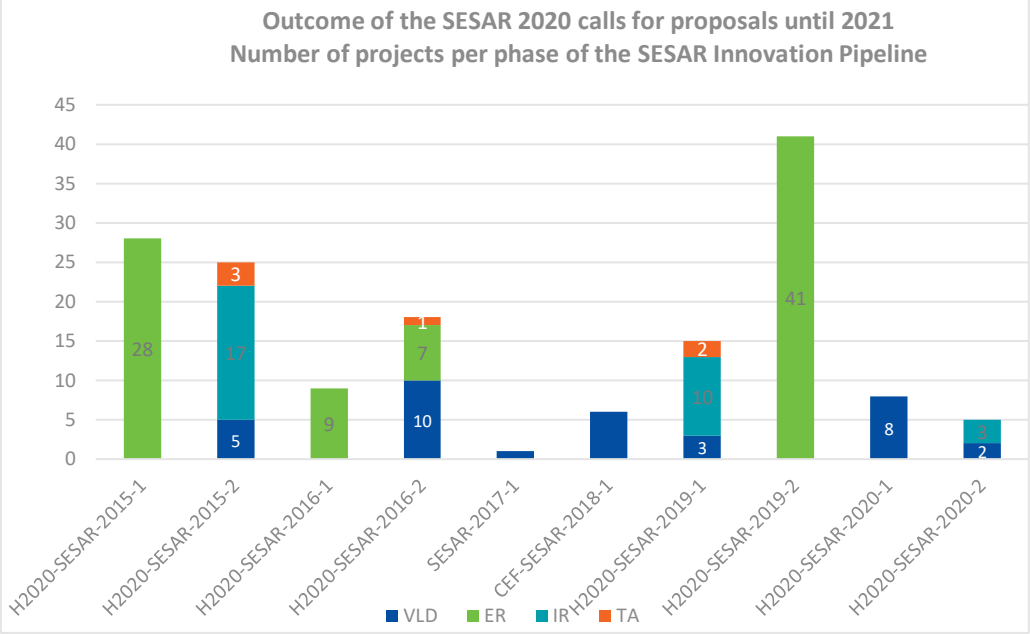


Figure 5: Number of projects per phase of the SESAR Innovation Pipeline, per call (end of 2021)

NB: TA, transversal activities

SESAR 2020 multiannual work programme

The portfolio of projects resulting from these calls is structured in accordance with the topics defined in the SESAR 2020 multiannual work programme (MAWP), as shown in Figure 6.

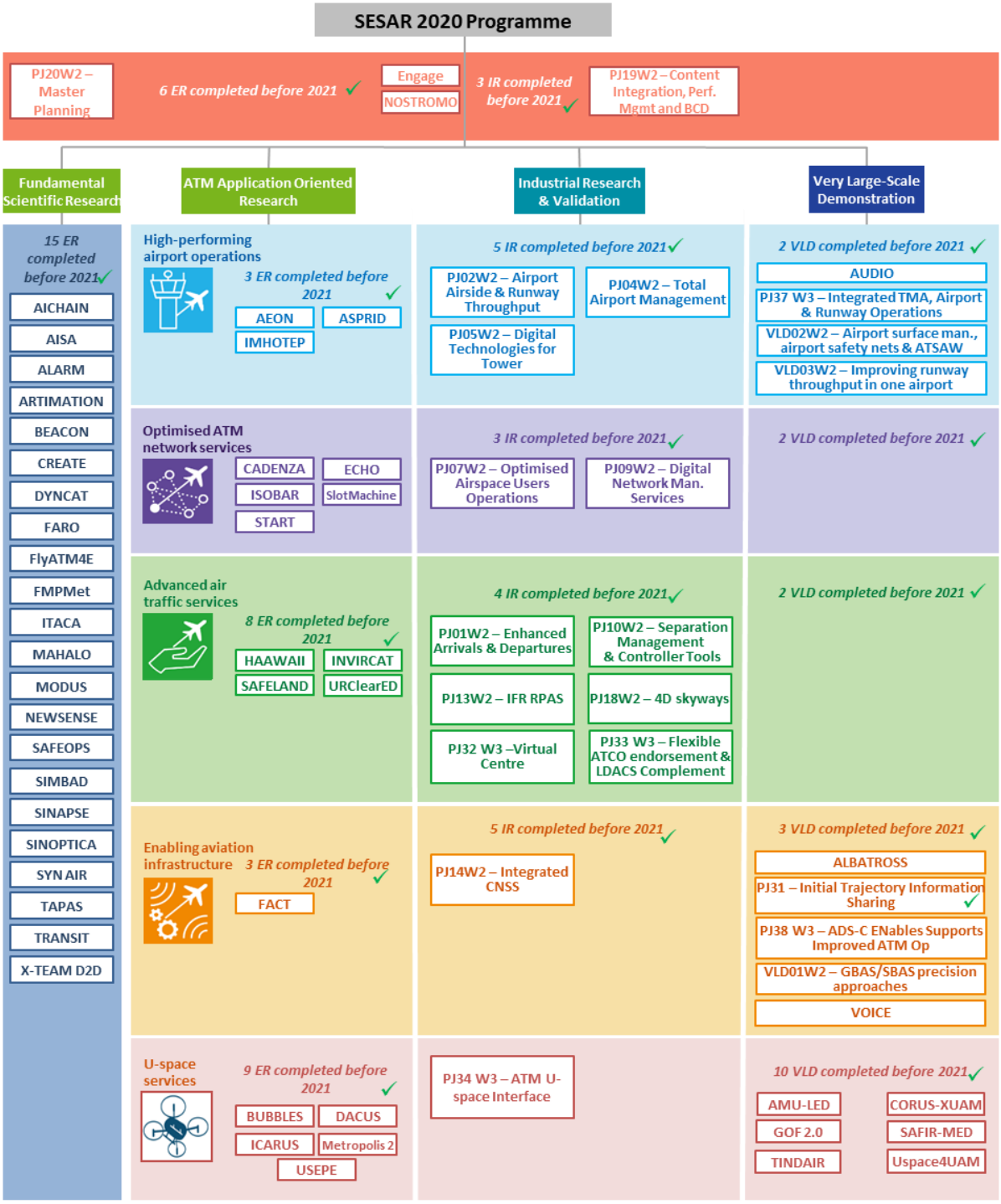


Figure 6: The SESAR 2020 programme portfolio of projects matching the research topics at the end of 2021 (projects in execution or closed) ([24])

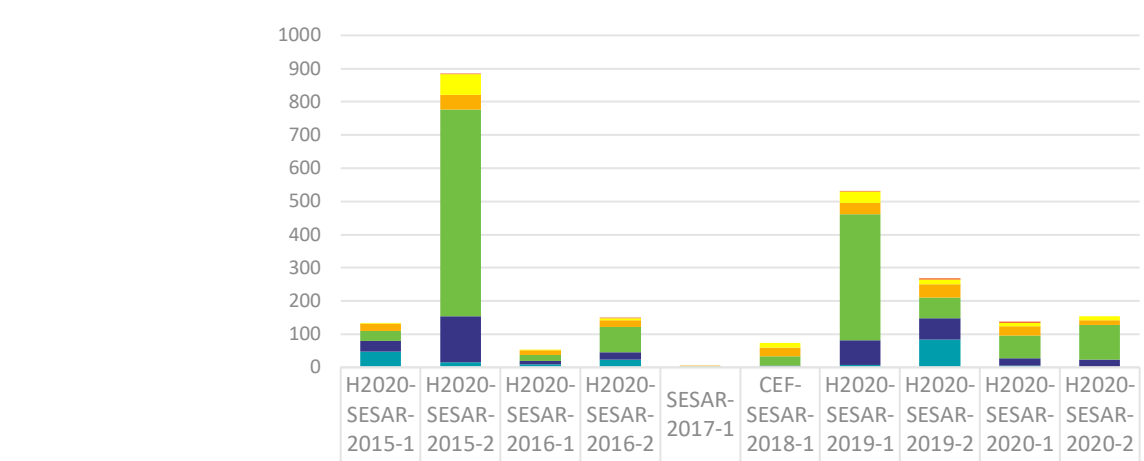
NB: 4D, four dimensional; ADS-C, automatic dependent surveillance contract; air traffic control officer (ATCO); airborne traffic situation awareness (ATSAW); , Business Case Development (BCD); communication, navigation and surveillance system

([24]) The figure shows 153 projects in execution or closed.

(CNSS); ground-based augmentation system (GBAS); instrument flight rules (IFR); L-band digital aeronautical communications system (LDACS); satellite-based augmentation system (SBAS).

A programme benefiting a broad range of stakeholders

All types of organisations targeted by H2020 are beneficiaries of the SESAR 2020 calls for proposals or linked third parties (Figure 7).



	H2020-SESAR-2015-1	H2020-SESAR-2015-2	H2020-SESAR-2016-1	H2020-SESAR-2016-2	SESAR-2017-1	CEF-SESAR-2018-1	H2020-SESAR-2019-1	H2020-SESAR-2019-2	H2020-SESAR-2020-1	H2020-SESAR-2020-2
Other	0	2	0	3	0	0	1	5	5	0
Public organisations	3	62	1	5	0	15	34	13	10	12
Private SMEs	21	45	14	21	3	25	34	40	28	13
Private companies (excl. SMEs)	30	622	19	76	3	28	380	64	68	104
Research organisations	32	138	9	22	0	3	73	63	22	22
Higher or Secondary Education Establishments	48	16	10	23	0	3	8	84	5	2

Figure 7: Number of beneficiaries of SESAR 2020 funding per type of entity

This funding is distributed across all 27 EU Member States (Figure 8).

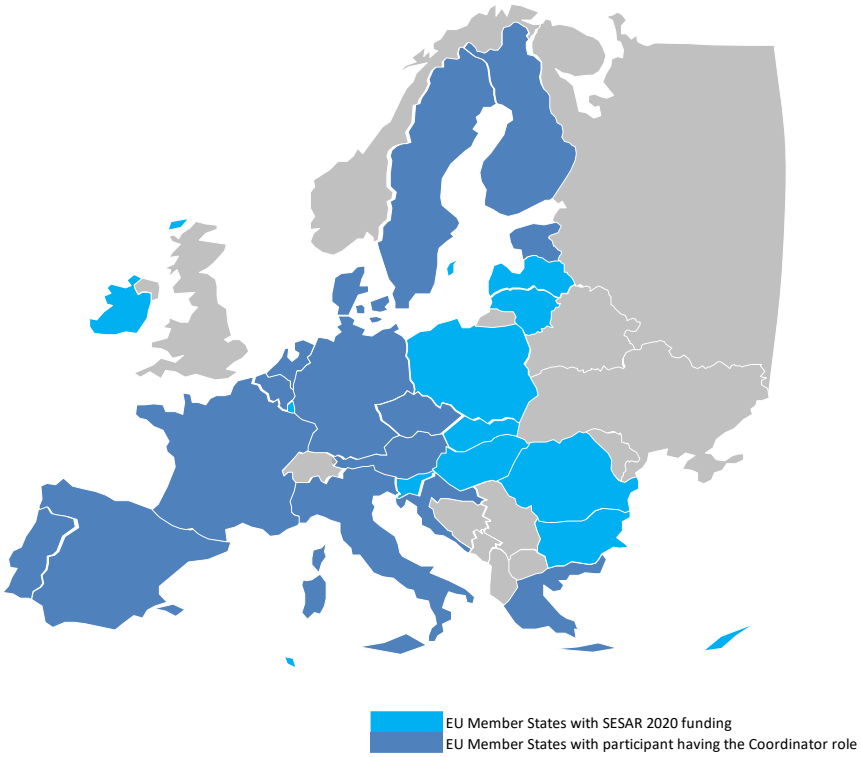


Figure 8: SESAR 2020 funding for EU Member States at the end of 2021

1.2 Implementation of calls for proposals and grant management framework in 2021

In 2021, the SESAR JU managed 71 grants already in execution at the beginning of the year, following five calls for proposals procedures conducted in previous years. All of these projects and the related grants were managed in accordance with the H2020 programme rules.

In addition, the grant agreement preparation for two projects from the reserve list of the VLD open 2 call for proposal (with reference H2020-SESAR-2020-1) was concluded in Q1 2021, representing a total value of EUR 7 269 850.

Furthermore, the SESAR JU set up specific measures to mitigate the adverse effects of the COVID-19 crisis on the aviation sector. In particular, the extension of the duration some grants has been allowed, providing the projects with more time to conclude their validations activities and to deliver the technical outcomes.

The sequence of all SESAR 2020 calls for proposals from 2015 to 2023 is shown in Figure 9.

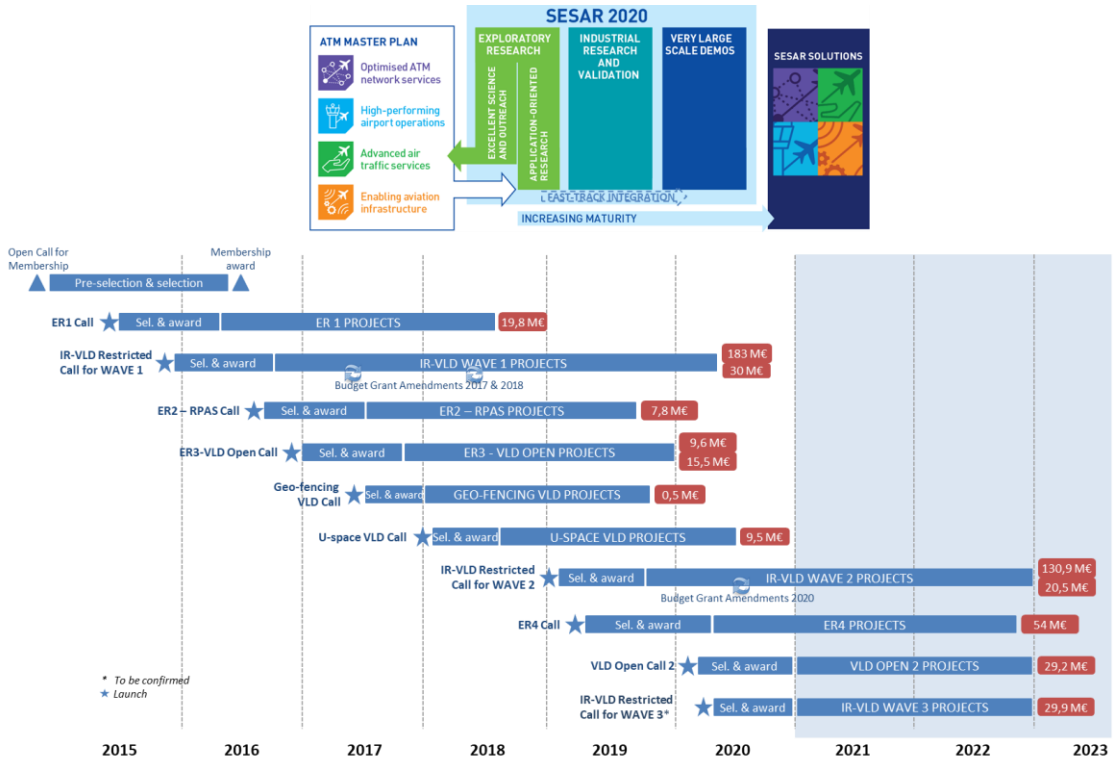


Figure 9: SESAR 2020 calls for proposals and their results at the end of 2021

1.3 Preparation of the SESAR 3 Joint Undertaking

The SESAR JU met all of its objectives related to the preparation for the establishment and launch of the SESAR 3 JU as outlined in Section III of the 2021–2023 single programming document (SPD). This includes the following achievements and results:

- preparing for the transition towards the future ATM partnership by developing and executing a transition plan;
- developing a MAWP for the SESAR 3 JU in line with the Digital European Sky Strategic Research and Innovation Agenda (SRIA), which was adopted by the Governing Board on 17 March 2022.

Over 2021, the SESAR JU supported the Commission in preparing the entry into force of the single basic act ([25]) setting up the SESAR 3 JU legal entity. The work was organised along two streams:

1. the definition of the MAWP, with a view to agreeing on the content and overall framework of activities to be carried out by the SESAR 3 JU from 2021 to 2031;
2. the transition of administrative and legal elements and preparation for the corporate, financial and administrative management of the SESAR 3 JU.

([25]) 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.

Furthermore, the SESAR JU provided support to the Commission in reviewing and providing feedback on key documents applicable for 2021–2031, such as the draft single basic act, the model grant agreement, the letter of commitment, etc.

1.3.1 Definition of the multiannual work programme

For the definition of the MAWP, the SESAR JU developed a structure to cover the following elements that establish the overall principles and framework under which the operations of the SESAR 3 JU will be defined, planned and carried out from 2021 to 2031. In particular, the MAWP introduces the following elements:

- the policy context of the SESAR 3 JU, which defines the relationship between the SESAR 3 JU and the main policy initiatives of the EU, namely the SES policy framework and the European Commission's sustainable and smart mobility strategy (including drone strategy 2.0) and European Green Deal and 'Europe fit for the digital age' priorities;
- the SESAR 3 JU's strategic objectives, which aim at building a Digital European Sky, as defined in the European ATM Master Plan (2020 edition), which is the main planning tool for ATM modernisation across Europe and connects ATM R&I activities with deployment activities and scenarios to achieve the SES performance objectives and the policy objectives of the EU; the objectives of the SESAR 3 JU are set in the single basic act;
- the overall R&I activities that the SESAR 3 JU will carry out from 2021 to 2031, referred to as the Digital European Sky programme, organised in the SESAR Innovation Pipeline; the content of the programe was defined using the draft SRIA as a main source, with the aim to ensure an optimal coverage of the priorities agreed upon by industry through the Digital European Sky programme;
- other activities necessary to achieve the strategic objectives, aiming to:
    - leverage synergies with other European partnerships and with national or regional ATM modernisation programmes;
    - ensure the engagement of institutional and industry stakeholders;
    - secure cooperation with non-EU countries and international organisations;
    - promote the SESAR 3 JU activities and results through communication initiatives;
- the governance of the SESAR 3 JU and the Digital European Sky programme.

The content of the MAWP was first developed internally by the SESAR JU, then shared with candidate members in order to identify possible showstoppers and to secure the buy-in of the main stakeholders. This was done through five workshops with candidate members from April to October 2021 (i.e. organisations identified by the European Commission through a call for an expression of interest procedure in 2020) supported by a circulation of iterative versions of the draft MAWP. These workshops were complemented with an open information day in September 2021, with a version of the draft MAWP dated 30 June 2021 accessible on the SESAR JU website. This approach and the MAWP presented were key in securing a new commitment by industry to contribute to the SESAR 3 programme to the level of at least the amount foreseen in the single basic act.

At the end of this process, at the end of 2021, the MAWP reached its final draft version and was ready to be submitted to the SESAR 3 JU governance bodies in view of their assessment and adoption planned in 2022. Once adopted, the MAWP will be the reference for all of the subsequent annual work programmes, the content of which will be defined to implement the principles set forth in the MAWP.

1.3.2 Smooth transition to the new legal entity: SESAR 3 Joint Undertaking

Over 2021, the entire organisation was mobilised and committed to a successful and timely shift towards the SESAR 3 JU.

For this purpose, SESAR JU developed several transversal coordination mechanisms, which allowed transparent and structured cooperation and relied on the individual expertise of each of the members of the organisation.

In particular, a Transition Coordination Group was established in February 2021. This group was composed of all members of the senior SESAR JU management and, for coordination purposes, involved representatives of the Directorate-General for Mobility and Transport ([26]).

Each member of this group had a significant stake in how each of the actions identified was managed.

Over 2021, the Transition Coordination Group met on a weekly basis to:

- identify and put together all of the goals, priorities and strategies for SESAR 3;
- undergo a debrief on each area's activities (tasks or contributions) and the related deadlines;
- identify and discuss how to best mitigate any risk of hampering the SESAR JU daily output;
- collectively seek solutions to achieve the set targets.

Internal experts were invited to participate in the Transition Coordination Group on a case-by-case basis as observers.

The group developed and maintained, until completion of the transition (set as the date of the first SESAR 3 JU Governing Board meeting on 14 December 2021), a centralised transition plan. This plan compiled all of the actions required and the related deadlines to structure transversal collaboration, report on the progress of the transition and ensure a smooth transition to the new programme.

In addition to the support given to the European Commission in the development of the new programme and its implementation tools (including a review of and comments on the draft single basic act, the Horizon Europe model grant agreement and the implementation of electronic tools), the transition activities were organised around three main pillars of activity:

1. transferring existing contractual, legal and operational material to the new organisation and/or adapting it to its new environment: this task resulted in a specific Governing Board 'ominibus decision' transferring those decisions adopted by the SESAR JU Administrative Board that apply, mutatis mutandis, to the SESAR 3 JU (Article 174.12 of the single basic act) ([27]) and Executive Director decisions, as well as amendments to existing contracts and service-level agreements (SLAs), an amendment to the SESAR 2020 membership agreement for the purpose of managing the SESAR 2020 projects transferred to the SESAR 3 JU, and a transfer of SESAR 2020 accounts and assets and liabilities;
2. the drafting of new decisions essential to the running of the new organisation from a daily management perspective;

([26]) The representatives were from unit E.3 on the single European sky and and from the shared resources unit.

([27]) This decision relates to a wide variety of topics including financial, human resources management, internal control and audit capacity, planning and other services (e.g. missions), as well as to transitional aspects (e.g. amended MA, 2020 accounts, and assets and liabilities).

3. allowing preparing for the kick-off of the SESAR 3 JU's activities: these decisions were developed around seven main objectives: establishing the governance mechanisms of the SESAR 3 JU, setting the R&I roadmap activities, determining future activities, ensuring the protection of integrity, protecting personal data and confidentiality, allowing the financing of new activities, and managing human resources (HR).

As a result of the transition stream, the SESAR 3 JU was able to start operating from day 1 (30 November 2021) as set out in the single basic act. The first meeting of the Governing Board of the new legal entity was successfully held on 14 December 2021 and adopted 19 first decisions (see Section III.3 on the Governing Board).

1.4 Operational achievements of the year

1.4.1 Strategic area of operation 1: Provision of strategic steering to the SESAR 2020 programme

1.4.1.1 Contributions of transversal steering projects

The SESAR JU met all of its objectives related to supervising the contributions of transversal activities and steering projects, as set out in Section III of the SPD for 2021–2023.

- Call for proposals with reference H2020-SESAR-2019-1 (IR-VLD wave 2 call for proposals): the supervision of wave 2 transversal activities. Projects PJ19 W2 and PJ20 W2 were in full execution over the course of 2021 and are expected to be closed by the end of 2022.
- Call for proposals with reference H2020-SESAR 2016-2 (ER3-VLD call for proposals) and call for proposals with reference H2020-SESAR-2019-2 (ER4 call for proposals). The ENGAGE and NOSTROMO projects were in full execution in 2021 and are expected to be closed by the end of 2022.

Two projects carried out within the IR strand of the SESAR 2020 programme address transversal topics, with a view to ensuring a coherent and consistent development of candidate solutions: PJ19 W2 on content integration, performance management and business case development and PJ20 W2 on master planning and maintenance. The achievements of these projects in 2021 are outlined below.

PJ19 W2: Content integration, performance management and business case development

Launched in December 2019, the mission of PJ19 W2 is to ensure that candidate solutions provide a coherent, consistent and validated view of how ATM performance can be improved and information can be integrated. In addition, the project enables and supports the process of capturing SESAR requirements to ensure traceability between the technical and operational requirements. It also enables the overall performance of SESAR Solutions to be assessed against the performance improvements expected for the European ATM system and set by the European ATM Master Plan.

In 2021, PJ19 W2 focused on and delivered in terms of the following main activities:

- the further elaboration of dashboards to follow and monitor content integration activities;
- the completion and delivery of output related to content integration (i.e. a service roadmap, services handed over to the system-wide information management (SWIM) governance, an architectural document, architecture baseline (i.e. DS21), and an update of the ConOp aligned with the ATM Master Plan vision and with the content of waves 2 and 3 of the SESAR 2020 programme);

- the set-up and maintenance of the system engineering repository and the provision of support for the work done by the solutions teams;
- training and coaching in performance matters for the people working in solutions teams;
- the final performance consolidation of SESAR wave 1 solutions and the delivery of the interim report on aggregrated performance (i.e. PAGAR, Performance Assessment and Gap Analysis Report);
- the defintion of new performance indicators related to digitalisation and the update of the performance framework to integrate U-space concept/solutions;
- the preparation of the consolidated CBA / business case contents to include 2021 achievements;
- the definition, prototyping and development of automated synchronisation between the system engineering repository and the architecture (European ATM architecture (EATMA) community) repository;
- the production of online architecture practices training material, in collaboration with the Eurocontrol Institute of Air Navigation Services (IANS) training department;
- the production and maintenance of both the public and working versions of the eATM 2021 Portal;
- contribution to the maturity gates as executed by the SESAR JU, as well as pre-coordination with integration leaders at the level of solutions teams.

PJ20 W2: Master planning

Launched in December 2019, the overall objective of the master planning project is to support the SESAR JU in its activities related to Master Plan evolutions. Within the SES technological pillar, the European ATM Master Plan is the long-term roadmap to guide and connect ATM R&I and deployment in building the future European ATM system and to reach the vision of the Digital European Sky. Essentially, it consists in maintaining, updating and publishing, as and when necessary, the European ATM Master Plan at all of its three levels (executive, planning and implementation). This work is monitored and reported on through transparent all-stakeholder categories and the key institutions involved in European ATM: the European Commission, EUROCONTROL, the European Union Aviation Safety Agency (EASA), the Network Manager (NM), the SESAR Deployment Manager (SDM), the European Defence Agency (EDA) and the European Organisation for Civil Aviation Equipment (EUROCAE).

In 2021, PJ20 W2 focused on and delivered in terms of the following main activities:

- the delivery of two Master Plan Levels 1 & 2 (MPL1-MPL2) assessment reports and the related MPL1-MPL2 assessment methodology: these reports monitor all changes introduced by SESAR development activities and highlight the significant changes in terms of alignment with the MPL1;
- support for MPL1-MPL2 alignment in the architecture and related change management and the development of associated criteria for maturity gate assessments;
- the development of the MPL3 report on the implementation objectives described in the ATM MPL3 plan for 2021;

- the development of the MPL3 plan for 2021, fully aligned with the Common Project One (CP1) regulation ([28]) and the SDM deployment programme, also including a view on SESAR solutions and the implementation objectives contributing to the airspace architecture study transition plan;
- the development of the standardisation and regulatory needs for 2021;
- support for an initiative taken by the SESAR JU and followed up at the level of the Master Plan Committee to create an action plan to simplify and strengthen all three levels of master planning processes; the support provided by PJ20 W2 consisted mainly in securing stakeholders' buy-in and in supporting the SESAR JU in the delivery of the action plan.

Concerning the work executed by both PJ19 W2 and PJ20 W2 in 2021 in relation to the COVID-19 pandemic, this had some impact on project staff availability and made collaboration between projects and partners more challenging. However, it did not prevent either project from delivering support services and deliverables on time, and there were relatively few delays.

In addition to the two projects providing transversal steering to IR projects, coordination in the field of ER is ensured through two projects: Engage and NOSTROMO.

The **Engage** project was launched in January 2018 in the context of the ER3 call for proposals to perform the role of SESAR 2020 KTN in support of the SESAR JU and is managed by a consortium of organisations from academia and industry. Its focus is twofold: to inspire new researchers and to help align SESAR ER and IR through a wide range of activities and financial support actions. The network aims, in particular, to stimulate the transfer both of the results of fundamental research to ATM application-oriented research and of application-oriented research to IR. The successful implementation of the innovation pipeline in SESAR 2020 will rely largely on the effectiveness of the KTN initiatives organised by Engage.

At the core of the network are four thematic challenges (TCs) proposed by the ATM community: TC1, vulnerabilities and global security of the communications, navigation and surveillance (CNS) / ATM system; TC2, data-driven trajectory prediction; TC3, efficient provision and use of meteorological (MET) information in ATM; and TC4, novel and more effective allocation markets in ATM. These were supported by dedicated workshops, which were held during the 4 years of the project.

Two calls for catalyst funding projects, published by Engage in 2019 and 2020, led to the selection of 18 projects, with a duration of 12 months and with a total budget of EUR 1.08 million.

The focus of the 18 catalyst projects was on maturing ER further towards applications and operational contexts. The eight catalyst-funded projects selected through the second wave have published their findings and have now closed.

To stimulate the next generation of interdisciplinary ATM researchers, Engage has also funded a PhD programme for 3 years with a total budget of EUR 830 000. The funded PhD students will mostly be reaching the end of their studies in 2022. All of the selected PhD students have been active in the workshop programme, the SESAR Innovation Days and the Engage Summer Schools. The third Summer School was held virtually in August–September 2021, with almost 100 participants from 20 countries.

([28]) 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) (OJ L 36, 2.2.2021, p. 10–38).

A total of six thematic workshops were arranged during 2021 in a virtual format, each one attracting over 60 participants. The workshops covered the following topics: data-driven trajectory prediction; efficient provision and use of MET information in ATM (27 January 2021, 70 registered participants); economic incentives for future ATM implementation; artificial intelligence, machine learning and automation; and the vulnerabilities and global security of the CNS/ATM system (15 September 2021, 72 registered participants).

Engage also supported the SESAR JU in the organisation of the 11th SESAR Innovation Days (held virtually) in December 2021 (see Section I.4.2.3.1).

As the closure of the Engage project approaches, the remaining activities in 2022 will contribute to the legacy of the KTN, through inspiring new researchers and helping to align ER and IR. The publication of a key deliverable will highlight future research opportunities for ATM. Promotional activities, such as video demonstrations of the EngageWiki[29] features, and continued support of the EngageWiki beyond the time frame of Engage, will help nurture future research opportunities and collaboration.

The second project is **NOSTROMO** (which focuses on next-generation open-source tools for ATM performance modelling and optimisation). One of the most challenging modelling problems facing the ATM research community is the assessment of the performance impact of new SESAR solutions at a system level, something that has been a long-time objective. The NOSTROMO project aims to develop new approaches to ATM performance modelling that can combine model transparency, computational tractability and ease of use with the sophistication necessary for a realistic representation of the ATM system. It does this by:

- developing a methodology for the construction of ATM performance metamodels;
- implementing the macromethodology by developing open-source metamodels of different state-of-the-art microsimulation tools and a set of visualisation and visual analytics tools that facilitate the analysis, interpretation and communication of the results;
- demonstrating and evaluating the maturity of the approach and the capabilities of the newly developed toolset through a set of case studies addressing the performance assessment of SESAR Solutions at European Civil Aviation Conference (ECAC) level.

The NOSTROMO project follows a three-stage iterative and incremental approach: implementation of case studies, followed by evaluation and correction.

In 2021, the project mainly focused on closing the first of the three iterations of the project and on performing the activities of the second iteration related to the development of metamodels and their interactive visualisations for facilitating the analysis, interpretation and communication of the results. In addition, the initial selection of the case studies was carried out with the aim of extensively validating the implementation and methodology of the project.

Owing to the COVID-19 pandemic, the collaboration of the project with many different partners was hampered. This resulted in some delays, but these were mitigated by some reworking of the initial plans.

[29] https://wikiengagektn.com/EngageWiki

1.4.2 Strategic area of operation 2: Delivery of exploratory research

The SESAR JU met all of its objectives related to ER in 2021, as set out in Section III of the SPD for 2021–2023. This includes the following achievements and results:

- the call with reference H2020-SESAR-2019-2 (ER4 call for proposals) on the execution of the H2020 Reporting and payments (REPA) including the projects review: 41 ER4 projects were in full execution over the course of 2021 and are expected to be closed by the end of 2022;
- ensuring the commitment of the scientific community regarding the SESAR topics: the Young Scientist Award took place in December 2021 as part of the SESAR Innovation Days;
- growing the SESAR Digital Academy: during 2021, the Digital Academy was active in organising webinars and activities aimed at developing the skills of the future ATM workforce.

The following sections outline the status of the ER projects that had ongoing activities in 2021. ER also encompasses other activities: SESAR Innovation Days, participation in relevant research events or forums and mechanisms set up by the KTN (e.g. PhD programmes), and workshops and open days arising from individual ER projects.

1.4.2.1 Status of exploratory research 3 call (within reference H2020-SESAR-2016-2)

The third open call for ER proposals, ER3, was opened in 2016 and closed in 2017. The first work area of the call also covered VLD open 1 call (see Section I.4.4.1.1). The resulting projects were launched into execution in 2018. Six projects funded under this call were closed in 2019 (as reported in the SESAR JU's 2019 consolidated annual activity report (CAAR)) and one further project, Emphasis, completed its activities in 2020 and was closed. One project, Engage, will complete its activities in December 2022. The activities of the Engage project in 2021 are described in Section I.4.1.1.

1.4.2.2 Status of exploratory research 4 call (with reference H2020-SESAR-2019-2)

The fourth open call for ER proposals, ER4, with reference H2020-SESAR-2019-2 ([30]), was opened in April 2019 and closed in September 2019. The ER4 call for proposals covered two different work areas.

1. Work area 1, ATM excellent science and outreach, aims to bridge the gap between ATM research and the wider research community and to provide the necessary scientific support to ATM change either directly or through connecting with research areas in other disciplines or sectors. Consequently, the purpose of this research area is to investigate which new technologies, methodologies, concepts or validation methods developed in the non-ATM sector could be introduced in the context of ATM and, in particular, could serve the SESAR business needs identified and the *Flightpath 2050* ([31]) vision or identify new ATM business opportunities. The scope of this work area is as follows:
    - automation and autonomy,
    - complexity, data science and information management,
    - environment and meteorology for ATM,
    - performance, economics, legal and regulation,

([30]) The call conditions were set out in the 2019 SESAR JU annual work programme. The call documentation is available on the Funding and Tenders Portal.

([31]) *Flightpath 2050* is a report of the High Level Group on Aviation and Aeronautics Research established by the European Commission in December 2010, setting out a new vision for the aviation sector to be achieved by 2050.

- ATM role in intermodal transport,
- CNS for ATM.

2. Work area 2, ATM application-oriented research, is intended to identify new concepts for ATM not already identified in the European ATM master plan, as well as emerging technologies and methods, and bring these to the level of maturity required to feed the applied research conducted in the SESAR JU. The scope of this work area is as follows:

   - high-performing airport operations,
   - advanced ATSs,
   - optimised ATM network management,
   - enabling aviation infrastructure,
   - ATM operations, architecture, performance and validation,
   - RPASs,
   - drones.

The total budget of the call was EUR 38 564 361, of which EUR 15 500 000 was allocated to work area 1 and EUR 23 064 361 was allocated to work area 2. The evaluation of the proposals was completed at the end of 2019 and the evaluation report was submitted to the Executive Director of the SESAR JU in January 2020. It was proposed that 29 grants be awarded and that a reserve list of good-quality proposals beyond the maximum budget be drawn up. Subsequently, 16 projects in work area 1, with a total value of EUR 15.6 million, and 13 projects in work area 2, with a total value of EUR 22 million, proceeded to the grant agreement preparation phase. The grant agreement preparation phase was completed in June 2020. In September 2020, an additional amount of EUR 15.4 million was made available (see Section III, subsection 2.6.1.4 in the 2020–2022 SPD), which allowed the SESAR JU to award 12 additional grants to projects on the reserve list (six in work area 1 and six in work area 2); the grant agreement preparation phase concluded in December 2020 with the signing of all grant agreements and the launching of the projects into execution. All projects are expected to complete their activities by the end of 2022.

The following sections outline the outcomes of the 41 ER4 projects in 2021 (in alphabetical order).

AEON

The advanced engine-off navigation (AEON) project kicked off in November 2020. The project aims to define a ConOps for engine-off taxiing techniques, making use of the following novel technologies that are coming onto the market.

- Non-autonomous taxiing technologies, such as TaxiBots. These are hybrid towing vehicles that, unlike normal pushback trucks, can tow full aircraft to near the start of the runway without the aircraft having to start its engines. This technology is expected to reduce fuel consumption during taxiing by 50–85 %.
- Autonomous taxiing technologies, such as the e-taxi system. These rely on electric motors embedded in landing gear, which allow planes to push back and taxi without their jet engines running, which saves fuel, reduces emissions and ends last-minute delays while waiting for airport tugs.
- Single-engine taxiing technologies. By using only half the number of engines installed to generate the energy needed for taxiing, taxi fuel consumption can be reduced by 20 %.

Importantly, fuel savings translate into reductions in carbon dioxide (CO_2) and nitrogen oxide emissions, while minimising engine use results in reduced noise.

The project, working closely with airports, airlines and aircraft manufacturers, aims to:

- develop an overall aircraft engine-off navigation ConOps, detailing how the three ecofriendly solutions can be combined in the airport surface management process at both strategical and tactical levels in order to minimise fuel consumption and emissions without affecting arrival and departure flight schedules;
- develop a business model to help airports and/or airlines evaluate the benefits of implementing these technologies;
- develop a real-time evaluation of environmental indicators to support decision-making and conflict-free routing for all vehicles;
- ensure the integration of its technical solutions into airport collaborative decision-making tools.

In 2021, the project delivered an initial version of the ConOps based on a study of the state of the art and interviews with the key stakeholders involved in such operations. The project team also initiated developments for a tugs fleet management algorithm and a routing suggestion algorithm, started the technical design and prototyping of the human–machine interfaces (HMIs) dedicated to air traffic control officers (ATCOs) and the tugs fleet managers, performed a preliminary integration of the prototypes in an airport simulation platform, and started the CBA activities.

AICHAIN

The AICHAIN project is based on developing a platform for privacy-preserving federated machine learning (ML) using blockchain to enable operational improvements in ATM. It is exploring an innovative digital information management concept (referred to as the AICHAIN solution) that aims to enable or facilitate the cybersecured exploitation of large private datasets that belong to different stakeholders, which contain valuable information to improve ATM operations. To overcome stakeholders' reluctance to share sensitive data, the exploitation of such data will not be performed by exchanging the data itself (data sharing) but by articulating an advanced privacy-preserving federated ML architecture in which neither the training data nor the training model need to be exposed (the ML is done locally and no private data leave contributors' hardware). The solution is based on the combination of the emerging technologies of federated ML and blockchain, as well as a set of governance and incentives protocols. The end goal of the AICHAIN solution – as a technology platform – is to enable an alliance of ATM stakeholders to set up a collaboration network of decentralised ML to enhance artificial intelligence (AI) ML models that are researched and/or used today in the context of ATM systems.

The AICHAIN project kicked off in July 2020, with three specific objectives:

1. to define the AICHAIN solution architecture as a potential SESAR technology enabler for the exploitation of private data value, and to implement a functional small-scale prototype for user validation and operational value experimentation;
2. to demonstrate and quantify the operational value of the AICHAIN concept with at least one ATM use case in the area of advanced demand–capacity balancing (A-DCB) services;
3. to develop an incentive mechanism that addresses the motivational aspects of data owners to facilitate the adoption and the effective utilisation of the AICHAIN concept.

During 2021, the following work was carried out to fulfil these objectives:

- the definition and design of (i) the AICHAIN intended solution, (ii) the small-scale experimental technology prototype, (iii) two operational proof-of-value research use cases including the preparation of the related datasets and ML models (use case 1 on take-off-time prediction and use case 2 on trajectory prediction) and (iv) the experimental and validation plan covering the

ML model improvement experiments and the technology assessment on cybersecurity aspects.
- the development and deployment of the technology prototype, having done two iterations, the first covering the federated ML platform components and the second adding the blockchain component (to test its use as a trust and auditability layer of the federated ML operations);
- the realisation of use case experiments of model improvement with the private data gathered, having already shown promising results of the value of airline private data (still in progress).

With respect to communication, dissemination and exploitation (CDE) activities, in addition to finalising the CDE plan and launching its project website, the project has:

- participated in the SESAR Innovation Days in December 2020 (poster presentation);
- set up its External Advisory Board, involving ATM stakeholder representatives (six airlines, two air navigation service providers (ANSPs), two airports and two related SESAR ER research projects) and two technology experts;
- conducted the first workshop with the External Experts Advisory Board, having validated the project hypothesis of the need to have incentive mechanisms as part of the solution;
- been presented at (i) the Second Annual Federated and Distributed/Decentralized Machine Learning Conference (16 June 2021) and (ii) the AerospaceTechWeek conference (Toulouse, 3–4 November 2021);
- coordinated with EASA for the inclusion of the AICHAIN approach in the EASA AI roadmap (project presented on 7 December 2021 to the EASA Member States Advisory Body Research Group).

AISA

The aim of the AI Situational Awareness Foundation for Advancing Automation (AISA) is to implement advanced automation, for which AI and humans need to be able to share situational awareness. To this end, the AISA project is exploring the effect of, and opportunities for, distributed human–machine situational awareness in en route air traffic control (ATC) operations. The project is developing an intelligent, situationally aware system by combining ML with a reasoning engine.

The project kicked off in June 2020. Its specific objectives are to:

- explore the effects of human–machine distributed situational awareness and opportunities for the automation of monitoring tasks in en route operations;
- identify the data needed by ATCOs to ensure that the proposed solution is correct (transparency) and to develop the method to provide those data;
- investigate methods for the adaptation of the automated system to changes in the environment, ensuring business continuity and safety.

During 2021, the following work was carried out to fulfil these objectives:

- the finalisation of AISA ConOps and requirements for the automation of system monitoring tasks;
- the development of three ML modules: conflict detection, four-dimensional (4D) trajectory prediction, and air traffic complexity estimation modules;

- the development of a mapping system that facilitates the transformation from information exchange models and that deals with data interchange and mapping between the Prolog program and the knowledge graph (KG);
- the analysis of the ATCO tasks in en route operations and the creation of logical links from the aeronautical information exchange model and flight information exchange model (FIXM) to the requirements identified;
- the development of a proof-of-concept KG system containing all of the relevant facts and rules required to model the en route air traffic situation;
- the adaptation of the user interface and functionality of EUROCONTROL's ESCAPE light simulator to perform real-time human-in-the-loop simulations and the creation of a set of relevant traffic scenarios;
- the execution of a series of simulations with 20 licensed ATCOs to gather data on human situational awareness and data to be used as input into the AISA system;
- the development of a data translator to feed data from the ESCAPE light simulator to the proof-of-concept KG system;
- the development of the functions representing the ATCO monitoring tasks.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, the project was presented at relevant conferences and workshops, such as the ER4 automation workshops (March and October 2021), the Engage workshop on automation, AI and ML (September 2021) and a EUROCAE WG114 meeting (July 2021). A paper on ML classification techniques applied to static air traffic conflict detection was presented at the European Aeronautics Science Network (EASN) conference in September 2021.

ALARM

The ALARM project aims to develop a prototype global multi-hazard monitoring and early warning system. Global multi-hazard monitoring relies on near real-time and continuous global Earth observations from satellites. The objective is to generate prompt alerts of natural hazards affecting ATM and to provide information that will enhance situational awareness and provide resilience in a crisis.

The project kicked off in November 2020. The project aims to integrate the following phenomena into its prototyped multi-hazard monitoring and early warning system.

- Severe weather conditions. Flying through a thunderstorm entails multiple risks (strong turbulence, wind shear, downbursts, icing, lightning and hail).
- Aerosols/gases from natural hazards, for example fire smoke, desert dust, volcanic ash and sulphur dioxide (SO_2) plumes. These hazards are less frequent than severe weather; however, their effects can be extremely disruptive. The use of space-based instruments enables the continuous global monitoring of natural airborne hazards in an effective, economical and risk-free way.
- Space weather. This is understudied as an aviation hazard. The effects on aviation include the disruption of radio/satellite communication (jeopardising very high-frequency (VHF), high-frequency and data-link communications, as well as those of RPAS); the degradation of navigation systems, for example GNSS-based procedures and magnetic compasses; and increased radiation exposure of crew and passengers and a higher risk of radiation-induced failures of on-board systems.

- Aviation-induced climate change due to emissions of greenhouse gases or their precursors. This is not currently considered in ATM decision-making. ALARM will integrate existing assessments obtained by previous studies to mitigate the climatic impact of aviation.

During 2021, the following work was carried out to fulfil these objectives.

- The definition and implementation of the multi-hazard monitoring and earl warning system data platform, which considers the recommendations from international entities (the World Meteorological Organization (WMO) and International Civil Aviation Organization (ICAO) framework) and takes observations from low Earth-orbiting and geostationary satellite detectors to deliver new early warnings (e.g a new selective detection of SO_2 and ash/dust clouds from geostationary broadband sensors).
- The development of a bias correction methodology, which uses hindcast numerical weather prediction data and satellite observations, for the nowcasting of SO_2 dispersion in localised airports.
- Thorough analysis of extreme weather climatology in Europe. A risk map was delivered. Milano Malpensa and Brussels airports were selected as the airports in which to develop the severe weather nowcasting algorithm. The nowcasting algorithm was developed based on the data in the Milano Malpensa area and it is now in the validation phase.
- Analysis of the climate impact of aviation emissions. The focus has been on the spatially and temporally resolved climate impact of non-CO_2 emissions, comprising the impact of nitrogen oxide emissions, water vapour and contrail cirrus. The underlying concept is based on spatially and temporally dependent prototype algorithmic climate change functions (aCCFs). The project has quantified the overall spatial and temporal non-CO_2 climate impact of aviation emissions (what has been coined merged aCCFs) and, using atmospheric weather data as input data (i.e. the European Centre for Medium-range Weather Forecasts (ECWMF) forecast), the climate impact of aviation emission can be determined. These merged aCCFs are the basis of the effective MET product ‘environmental hotspots’, which will be integrated into the ALARM early warning system platform. Thus, aviation-induced climate change can be considered in ATM decision-making.
- The usage of combined alert products (derived from observations and model outputs) to create tailored products dedicated to ATM. An assessment of the state of the art has been conducted on the provision and distribution of the information in ALARM modules: severe weather, natural hazards (i.e. volcanic ash and SO_2, dust, and fire) and environmental hotspots. The information provision flows, existing regulations and standards (e.g. the ICAO meteorological information exchange model (IWXXM) format for MET information exchange) for each of the modules have been assessed and a map has been created of information provision and distribution. A data platform accessible by users and ALARM partners was then created. The initial visualisations of different alert products has been prepared in a web application programming interface, which was demonstrated at the stakeholder workshop.

In terms of CDE activities, ALARM has used the web and social media (Twitter and LinkedIn) as the main media to position the project. Information on the project has been disseminated at eight events, including the Engage workshops and SESAR Innovation Days. In addition, ALARM has conducted two outreach campaigns and created three posts for communication purposes. ALARM has also organised a workshop to identify requirements and it is working towards exploiting the outcomes of the workshop (via the Alert system platform -ALARM service for early warning alerts) and creating a library on the climate impact of aviation.

ARTIMATION

The ARTIMATION project aims to investigate the use of AI methods to predict air traffic and to optimise traffic flows based on explainable artificial intelligence (XAI) to address the challenge related to the transparency of automated systems in the ATM domain. ARTIMATION will provide proof of concept of a transparent AI model that uses visualisation, explanation and generalisation to ensure safe and reliable decision support.

The project was kicked off in January 2021 with the following specific objectives:

- to provide transparency and explainability to the AI algorithms based on data-driven storytelling, immersive analytics and visualisation, with the goal to predict air traffic conflict resolution and delay propagation;
- to develop a conceptual framework for building human-centric XAI based on an extensive review of the application of XAI techniques; the new transparent and explainable models developed are intended to be acceptable to the ATM operators in their decision-making tasks based on a closed loop of the operational procedure and user test;
- to predict air traffic conflict resolution and delay propagation based on machine lifelong learning and the integration of causality thanks to a new generalised and optimised AI model;
- to prepare user guidelines for the development and application of AI algorithms, providing transparency in the ATM domain with the goals of predicting conflict resolution and delaying propagation.

The project will develop a human-centric AI model that will be assessed by ATM operators. During 2021, the following work was carried out to fulfil these objectives:

- delivery of an assessment of the state of the art in AI and XAI in ATM, addressing the strengths and weaknesses of currently used techniques;
- delivery of specifications regarding the application of AI-based solutions in ATM and the related support in operational activities, together with a roadmap for developing the proof of concept of an XAI system;
- a review of the possible neurophysiological measures for processing algorithms and technologies that could be employed during the experimental activity;
- the development of the validation plan, defining the experimental design, the validation platform requirements, the indicators for assessing the human performance and user acceptability, and the validation success criteria for the conflict resolution and delay propagation use cases.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, two scientific papers were published in *Applied Sciences – Computing and Artificial Intelligence* (a special issue on XAI). The project was also presented at the 11th EASN International Conference and at the 43rd Annual International Conference of the Institute of Electrical and Electronics Engineers (IEEE) Engineering in Medicine and Biology Society. Regular coordination is also sought with other related projects (e.g. AISA, MAHALO, SafeOPS and TAPAS).

ASPRID

The airport system protection from intruding drones (ASPRID) project kicked off in November 2020. The project explores the definition and initial validation of a service-oriented operational concept and system architecture to protect airports from intruding drones, either by mistake or through malicious

intent. The project aims to analyse aircraft and airport (runway and surface) operations, exploiting all of their related attributes to assess if and in what way they are vulnerable to different identified use cases of intruder attacks and how non-nominal scenarios can evolve. This analysis should result in the definition of a solution that, tuned to a specific situation, could bring the airport back to nominal conditions within acceptable time constraints.

The project's specific objectives are to:

- determine how critical aircraft and airport operations might be adversely affected by drone intrusions;
- define a complete concept of an innovative single-platform system architecture, supported by procedures and regulation issues, to manage both airport intrusion and airport operations efficiently;
- validate the system architecture according to safety and security performance objectives.

The main benefits expected from the development of such a solution are improvements in safety, security and resilience to disruptions from the operational and economic perspectives.

In 2021, the project performed the following activities:

- the definition of risk scenarios based on the analysis of historical data related to drone intrusions;
- an assessment of the vulnerabilities of airport operations and the definition of a list of critical operations;
- the initial description of the operational concept, requirements and architecture for a drone intrusion detection and mitigation system;
- the initial definition and preliminary design of a decision support system for the mitigation of drone intrusion risks;
- the development of a preliminary validation plan and a prototype demonstration;
- a review of the drone-related regulations and the development of an initial proposal for their evolution considering the concept under development.

BEACON

The behavioural economics for ATM concepts (BEACON) project aims to study the feasibility of extending the user-driven prioritisation process (UDPP) to allow multi-prioritisation processes in the airspace and the exchange of slots between airlines. It will build two models: a strategic model and a detailed tactical simulator. To capture the agents' behaviours properly, BEACON will make use of behavioural economics.

The project kicked off in July 2020 with the following specific objectives:

- to propose a set of improved flight prioritisation mechanisms that expand current UDPP capabilities;
- to define new metrics to evaluate the fairness and equity of flight prioritisation mechanisms and validate their appropriateness with AUs;
- to quantify the impact of 'non-rational' behaviours of AUs on the outcome of the proposed mechanisms, taking advantage of the methods and tools developed in the field of behavioural economics;

- to integrate the insights gained from behavioural economics into an agent-based microsimulation model of the full ECAC network able to capture network effects;
- to run a set of simulation experiments to evaluate the impact of the new UDPP mechanisms on the selected key performance indicators (KPIs), taking into account behavioural effects, in order to analyse the advantages and the risks with respect to current UDPP capabilities;
- to derive guidelines and methodological recommendations on the further development, validation and deployment of the new UDPP mechanisms that pave the way towards a more harmonised and efficient flight prioritisation process across Europe.

During 2021, the following work was carried out to fulfil these objectives.

- A discussion was held of three alternative mechanisms for extending the UDPP process: a centralised optimiser, using input similar to the current UDPP; a centralised credit mechanism; and a primary auction mechanism. One mechanism (the credit mechanism) was then selected, with the help of all partners in the consortium.
- A set of scenarios were defined that simulate typical situations in which the mechanisms can be used by AUs.
- A questionnaire was designed and launched several times to provide data for the calibration of behavioural functions used within the models. A literature review was performed to complement the survey in order to estimate some parameters of the decision-making process.
- As a result of previous work, the project developed a new model, smaller in scale and computationally less expensive, that, in particular, focused on integrating the hotspot library and developing the other mechanisms.
- In this framework, the project also created a hotspot library that allows a hotspot to be solved using different algorithms, including a standard UDPP algorithm, a new algorithm and other algorithms used as benchmarking.
- An HMI was developed in order to perform human-in-the-loop simulations, using one of the models, Mercury, as backend. The hostpot library was integrated and the credit mechanism development started in 2021.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, the project was presented at relevant events and workshops such as the SESAR Innovation Days in 2021 and the Engage thematic workshop on economic incentives for future ATM implementation. It was also presented at the Airline Group of the International Federation of Operational Research Societies (AGIFORS) Airline Operations Study Group meeting on credit-based mechanisms for user-driven prioritisation during air traffic flow management (ATFM) regulations. In addition, regular meetings were held with the Advisory Board composed of representatives of EUROCONTROL, HungaroControl, NATS, ENAIRE, Skyguide, Air Baltic, El Al, Hop!, Schiphol Airport, Zurich Airport, Frequentis and Deep Blue.

BUBBLES

The BUBBLES project focuses on defining the building basic blocks for a U-space separation management service. In brief, the project objectives are to:

- formulate and validate, using a preliminary prototype, the EOCVM V1 maturity of a ConOps for the provision of separation management by U-space services;

- assign pairwise separation minima and maintain them so that the expected safety level is achieved, taking into account the available U-space services and the performance of the CNS systems therein;
- specify the required U-space CNS performance requirements, as well as compliance assessment methods, so that the benefits of the performance-based CNS concept can be extended to U-space;
- draft a safety and performance requirements (SPR) document and compliance assessment methods for the services providing environmental information relevant to the provision of separation minima and methods for unmanned aerial systems (UASs);
- efficiently disseminate the project results in order to make both the involved stakeholders and general public aware of the enhancement of UASs' operational safety attained through U-space.

During the reporting period, the following work towards the achievement of the above objectives was carried out:

- An initial concept was formulated following the methodology described in Annex 1 of the grant agreement. An initial operational services and environment description (OSED) / safety and performance and interoperability requirements (SPR-INTEROP) document was under development to attain safety criteria, which were expressed in terms of different conflict rates in order to guarantee a given TLS. In addition, a high-level validation plan was developed.
- A collision model that takes into account the performance of CNS systems was developed. Based on this collision model, an AI-based system was developed and trained using representative trajectories to assign separation minima and methods so that the collision rate associated with a given TLS could be achieved. In addition to the TLS and the CNS performance, the definition of separation minima took into account the aircraft density, the traffic mix and the associated operational risk, and the U-space services and ATSs available in a particular airspace sector.
- BUBBLES specificed the required U-space CNS performance requirements. During the reporting period, the pre-existing hazards were derived and quantitative safety criteria were defined. Safety arguments were formulated, leading to the allocation of safety objectives based on the U-space services contributing to the separation management and the CNS systems supporting them. The development of compliance assessment methods for communication and surveillance systems supported the provision of separation management by U-space set out during the reporting period.

The collision model developed by BUBBLES takes into account the effect of wind on the collision rate. Weather has also been considered among the pre-existing hazards addressed in the MEDUSA safety assessment. Therefore, safety arguments, objectives and requirements will be allocated to the U-space weather service.

As part of the BUBBLES project, a CDE plan was developed, which includes the corresponding strategies, tools and planned actions to achieve the project's objectives. Communication and dissemination activities have been executed according to the plan, with a few minor changes introduced to tackle the effects of COVID-19.

CADENZA

The CADENZA project focuses on advanced capacity and demand management for European network performance optimisation. It kicked off in 2020 and aims to develop a detailed trajectory broker concept for the European network, incorporating advanced DCB mechanisms. The trajectory broker

will balance capacity and demand through a coordinated capacity provision process and collaborative trajectory management (including a novel trajectory charging scheme).

CADENZA covers all areas of capacity provision (en route, terminal area and airport), as well as all temporal levels (strategic, pre-tactical and tactical). The project is expected to achieve significant improvements in cost-efficiency and to have positive impacts on other KPIs, in particular a reduction in delays. The CADENZA concept will be thoroughly validated, using mathematical models and comprehensive real-world data.

The project team has defined five specific objectives for the project, which are to:

1. explore several variants of a trajectory broker concept with a range of options for advanced DCB, along with supporting organisational and regulatory changes and, with stakeholder input, select and develop the most promising ones;
2. in the case of the selected options, develop suitable advanced DCB processes in temporal (strategic, pre-tactical and tactical levels) and spatial (en route, terminal airspace and airport) dimensions, including technical aspects thereof;
3. develop mathematical models to support decision-making at all three temporal levels mentioned in the second objective, with the aim of improving overall network performance;
4. evaluate the network performance of the selected trajectory broker concept and advanced DCB options (including carrying out extensive sensitivity analyses) and compare the selected solutions against a baseline to identify key performance-improving drivers, as well as potential showstoppers;
5. increase stakeholder buy-in by actively involving key stakeholder representatives in all phases of the project, as well as through targeted communication and dissemination activities.

To fulfil these objectives, the project team executed several activities in 2021.

- An initial sensible framework was produced for network performance optimisation, including an adequate re-design of the roles and relationships between key stakeholders in the ATM value chain, to support the potential introduction of a trajectory broker figure, and promising advanced DCB options were identified.
- The AU choice models when planning trajectory options in negotiation with the trajectory broker, and when facing different sources of uncertainty at different time horizons, were defined. In addition, a task was initiated for defining and developing the ANSP models for defining different levels of temporal and spatial capacity provision flexibility.
- The initial mathematical models were produced, which were needed for network optimisation and the capacity and demand management decision-making process. For testing the defined models, the initial validation task was executed.

CREATE

The focus of the CREATE project is climate and weather models to improve ATM resilience and reduce its impact. The project aims to develop innovative procedures in ATM to reduce the climate and environmental impact of aviation, while increasing the resilience of air operations to weather phenomena. To address this challenge, the project aims to look at the ATM system primarily from the perspective of en route operations, with a focus on minimum environmental and climate impact, and secondarily from the perspective of TMA operations, which include approach/departure operations near airports, with a focus on local air quality and noise load.

CREATE kicked off in July 2020. The aims of the project are to:

- study the vulnerability of the ATM system with respect to weather phenomena, in order to improve ATM procedures so that vulnerability can be reduced;
- study the impact of aviation on the environment, in both the short and the long term (as regards climate), in order to propose ATM operational changes able to reduce this impact;
- study possible new MET tools and methodologies, in order to integrate their use into ATM;
- validate proposed ATM operational changes in order to reduce the ATM environmental impact and improve ATM resilience with respect to weather.

The most important achievements during 2021 were the following.

- An advanced system for studying the impact of air quality at different spatial and temporal scales was designed. This system was used to estimate the effects of aviation on climate, and the impact on air quality at regional and local scales, with the quantification of emission intensities and areas of impact for airports of different sizes and traffic levels. This system was further evolved to study the impact on the microscale, taking into account the detailed effects of dispersion processes, from each aircraft along a specified trajectory.
- Dedicated studies were carried out aimed at identifying the most significant MET phenomena affecting ATM operations, their main impact in terms of operational disruptions and the relative level of severity. An analysis of the expected climate variability was performed, considering suitable extreme event indicators, both on past trends and on numerical projections over future periods, aiming to contribute to the definition of a risk assessment methodology based on the frequency and the severity of MET hazards.
- Weather ensemble forecasting models, allowing high-resolution and short-range forecasts, were set up. These tools were designed to provide weather data for trajectory replanning at tactical level, while also taking into account the impact on the environment (the emission of air pollutants) and climate (the emission of greenhouse gases and radiative effects).
- A trajectory optimisation framework was developed. The framework contains elements (i.e. components) addressing trajectory optimisation with respect to multiple AUs, aiming to tactically avoid severe weather areas and climate-sensitive areas based on advanced numerical weather prediction models, by proposing optimised candidate trajectories. The framework also contains a dedicated DCB element, addressing the ATC / network operator need of assuring compatibility between demand and sectors' capacity, aiming to select a global optimum among the proposed candidate trajectories.
- Several use cases were considered to demonstrate the effectiveness of the ConOps. The ConOps will be applied to two use cases – en route and TMA – to assess the effectiveness of multi-aircraft environmentally scored weather-resilient optimised 4D trajectories. The solution would allow the avoidance of thunderstorm areas (to mitigate weather-induced ATM delays, thus increasing weather resilience) and contrail-forming regions (to mitigate the aviation-induced climate impact).

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, additional activities were carried out, including participation in relevant workshops (i.e. the 10th International Workshop on Advances in Cleaner Productions), an international conference and the SESAR Innovation Days.

DACUS

The focus of the DACUS project is on the demand and capacity for U-space optimisation. It aims to develop a service-oriented DCB process for drone traffic management. The project intends to integrate in a consistent DCB solution the relevant factors influencing demand and capacity (e.g. CNS performance availability), definitions (e.g. airspace structure), processes (e.g. separation management) and services (e.g. strategic and tactical conflict resolution).

Five specific objectives were set for this project, namely to:

1. develop a drone DCB process, from the strategic phase to the tactical phase, integrating uncertainty and U-space performance metrics for airspace capacity;
2. develop innovative service algorithms, models and technologies to support a large number of simultaneous operations and to design and manage efficient and safe drone trajectories;
3. define a structure for very low-level airspace and a set of airspace rules that optimise the trade-off between capacity and safety;
4. find the optimal balance between on-board and ground intelligence in tactical separation;
5. refine CNS requirements in support of tactical and procedural separation, with a focus on the urban environment.

During the reporting period, the work progressed according to the initial plan. The following work towards the achievement of the above objectives was carried out.

- The project defined a preliminary ConOps for DCB of drone operations within an urban environment.
- The project progressed through the definition of requirements of key U-space services that are part of the DCB process. In particular, the dynamic capacity management service, which is at the core of the overall process, will rely on three models that are being developing by DACUS. In addition, DACUS is also developing microweather models applicable to urban environments, as well as new functionalities for the operation plan preparation and processing services.
- DACUS characterised urban environments from the perspective of expected ground infrastructure, airspace design, CNS performances and local regulatory frameworks in order to define the boundary conditions for the implementation of DCB processes in U-space.
- DACUS is performing a wide range of validation experiments to test the suitability and performance of the various prototype algorithms under nominal and subnominal operating conditions. As the starting point for this task, DACUS developed a separation management process that fit into the previously designed DCB ConOps, providing a description of the set of principles and assumptions that will be applied to describe separation management, as well as the responsibility roles that are going to be set. A preliminary set of CNS requirements will be defined in support of the separation minima criteria and the separation management process.

DYNCAT

The dynamic configuration adjustment in the TMA (DYNCAT) project aims to enable more environmentally friendly and more predictable flight profiles in the TMAs, namely on approach, by supporting pilots in configuration management.

DYNCAT aims, in particular, to demonstrate the potential for 4D trajectories to be optimised by taking into account environmental considerations, specifically CO_2 and noise levels, and to make the changes needed for safer, more cost-effective and more environmentally sustainable operations in TMAs.

DYNCAT kicked off in July 2020. Its objectives are to:

- highlight the impact of current (approach) ATM operations in the TMA on environmental pollution, cost-effectiveness and safety, based on actual flight data;
- quantify the potential to reduce CO_2 emissions and noise in real life (through aircraft source noise models available at the DYNCAT consortium);
- measure the improvements in flight predictability and flyability (pilot workload and safety) achieved by the implementation of novel pilot support functions, with a focus on optimisation of high-lift system actuation for low-noise approaches within the extended TMA (E-TMA);
- derive measures to be implemented in the short term (mainly on-board procedures) and mid-term (mainly new on-board system functionalities) and identify the necessary enablers, such as new technological functions (supportive tools and data exchange) and regulatory changes, to allow improved airborne procedures.

In 2021, the project assembled and critically analysed the required datasets on real-life operations in order to allow the analysis of individual flights in their operational contexts and weather conditions. Owing to the COVID-19 pandemic, the measurements originally planned could not be performed, but it was possible to obtain historical data and consolidate them, albeit with an increased matching and simulation effort.

The analysis showed the dependencies and effects of different common situations at the example airport Zurich, illustrating the bandwidth of pilots' and ATCOs' handling of these situations and the consequential impact on noise, fuel consumption and safety margins such as approach stabilisation. A critical analysis of current operations describes the results in detail and shows the potential for improvements. The analysis and conclusions were debated in a workshop with a broad international group of participants consisting of air traffic controllers, pilots and experts from various air transport authorities including the US Federal Aviation Administration (FAA), EUROCONTROL and Deutsche Flugsicherung (DFS), the German air traffic control service.

Based on the analysis and the experts' recommendations, the project developed an initial operational concept to support pilots and controllers in their tasks in the TMA in order to decrease fuel burn and noise exposure. It points out which parts of the current applied processes, regulations, tools and systems need to be changed or extended. The initially concept describes the expected positive and negative effects in terms of fuel burn and noise exposure, as well as other factors such as workload for controllers and pilots, the throughput at airports and safety.

Relying on this operational concept, a high-level system definition was developed to support the exemplary prototyping of the most relevant additional airborne capabilities, with the objectives being to prove the viability and to demonstrate the potential of the new concept during the upcoming real-time simulation (RTS) exercise. System requirements for the flight management system and cockpit display system were specified, and a validation plan was delivered.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, various activities were undertaken, including participation in webinars, workshops and congresses and the publication of articles in corporate magazines and on the SESAR JU's website. Coordination and exchanges with other SESAR projects, including FlyATM4E and PJ01 W2-08b, was also ensured.

ECHO

The European concept of higher airspace operations (ECHO) project, which kicked off in 2020, will deliver a comprehensive demand analysis and a comprehensive, innovative and feasible ConOps enabling near-term and future higher airspace operations in a safe and orderly manner.

New AUs and operations are increasingly emerging in this higher airspace. There is a broad diversity of vehicles, ranging from unmanned balloons, airships and solar planes capable of persistent flight, collectively known as high-altitude platform systems, to supersonic and hypersonic aircraft and transatmospheric and suborbital vehicles. Commercial and state space operations are also transiting through the higher airspace for launches and re-entries.

The work of ECHO on the future definition of a European ConOps for higher airspace will feed into the ICAO global framework, ensuring a global harmonised approach for higher airspace operations. It will also constitute the foundation and the starting point for the development of the future European higher airspace operation regulatory framework by EASA.

The project undertook an investigation into high-altitude operational concepts and analysed the information collected. The ECHO project focused on terms and definitions in order to consolidate the expected content of the studies and the boundaries of the higher airspace, and started to define the scenario, the use case design of the concept, the vehicles and the operation specificities. When defining the higher airspace traffic management principles in this reporting period, the project team focused on the user requirements.

The ECHO team arranged a workshop to get feedback from the relevant stakeholders, with the intention of reflecting the outcome of this event in the deliverables. Unfortunately, not enough responses were received from the stakeholders, which led to delays in the delivery of the deliverables planned.

The ECHO project is also participating to the EASA Higher Airspace Operations Task Force, which was set up to carry out preparatory work for the future higher airspace operations regulation.

FACT

The future all-aviation CNS technology (FACT) project kicked off in July 2020. The overall objective of the project is to take a fresh look at the validated technical CNS/ATM building blocks that can support current and future air traffic challenges in the most cost-effective way. The project focuses on safety, security, performance, efficiency and robustness, through the development of an integrated CNS (iCNS) functional architecture.

By addressing both existing and new AUs, such as drone or urban air mobility (UAM) operators, the project aims to build a bridge between future U-space (expected to be fully digital and highly automated) and conventional ATM systems, considering both technological and users' perspectives.

The project adopts the following, more specific, iCNS design objectives:

- to enable advanced services, extensive operational data collection and efficient information-sharing among different service providers and AUs;
- to improve access of general aviation to airports and airspace through smooth integration within commercial aircraft operations, which will be achieved primarily through interoperable surveillance, increased navigation performance and flight information service / MET information provision;

- to enable access to airports for new users such as UAM vehicles and drones – typically within segregated airspace, but with the option for gradually supporting their full integration into airspace;
- to enable the evolution of autonomous operations for drones and UAM vehicles;
- to improve the resilience of GNSSs within the proposed iCNS;
- to enhance the resilience of nominal and non-nominal operations to emergency situations affecting operational safety and security.

The iCNS capabilities will be validated for selected operational use cases. This will be done in real environments, using experimental demonstrators developed in the project.

The project completed the initial versions of the ConOps, functional architecture and system requirements in 2021.

FARO

The FARO project focusing on safety and resilience guidelines for aviation aims to bring new insights about safety and resilience into ATM, with four objectives: to exploit existing safety knowledge, to quantify the impact of increasing automation on ATM safety, to analyse the impact of increasing automation on ATM resilience, and to provide design guidelines and identify future research needs.

FARO kicked off in May 2020. The objectives of the project are to:

- define a conceptual framework that enables the evaluation of safety and resilience performance in terms of the technical, organisational, human and procedural characteristics of the ATM system;
- generate predictive models of safety events as a function of the technological, organisational, human and procedural dimensions associated with an automation solution to quantify the likelihood of safety events as a measure of the safety level;
- analyse the impact of higher levels of automation on ATM resilience;
- research system resilience performance (absorptive, restorative and adaptive capacity) by characterising it as a function of performance variability, brittleness and adaptive capacity;
- develop a set of guidelines to facilitate the definition and evaluation of the safety and resilience criteria associated with a new automation solution;
- find research gaps by evaluating the impact on safety and resilience of the selected automation solution and thereby identify research and development (R&D) needs in the field of safety and resilience in ATM.

During 2021, the following work was carried out to fulfil these objectives:

- a review of the state of the art in safety and resilience engineering;
- a description of the use cases that have been developed in the project and a definition of a safety and resilience conceptual framework for our case studies;
- the development of a baseline model of the safety performance functions for particular ATC sectors – as part of the deliverable focused on the applicability of the safety performance functions, the generic SPF baseline model was adapted to the sectors analysed in the project, and influencing factors and applicability thresholds were derived; the deliverable also developed a graphical scheme to present the outcomes of the models;

- the delivery of a resilience model description for the ATM system through the use of resilience engineering and systems theory to assess and understand the resilience performance of the work system and the strategies used by all actors to adapt to varying operating conditions;
- the development of a validation plan, defining and setting the basis for a demonstration of usability that will be performed on selected concept use cases.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, various activities were performed as part of the project, including participation in relevant conferences, congresses and workshops. These included the SESAR Innovation Days in 2021 and the 11th EASN conference (September 2021), with the presentation of the paper 'Safety performance functions to predict separation minima infringements in enroute airspace'. The intermediate results of the project were presented to ENAIRE's safety monitoring team and to the NATS R&D team, and exploitation routes for the models developed were discussed.

Meetings with its Advisory Board are organised regularly, involving LFV, Iberia, CANSO, ENAIRE and EUROCONTROL, regarding exploiting the project results.

FlyATM4E

The flying ATM for the benefit of the environment and climate (FlyATM4E) project aims to expand approved climate assessment methods and the optimisation of aircraft trajectories to identify promising mitigation options suitable for addressing the task of reducing the overall climate impact of aircraft operations. The project is assessing the feasibility of a concept for the environmental assessment of ATM operations, working towards the environmental optimisation of air traffic operations.

The project kicked off in June 2020 and has the following objectives:

- to advance concepts for assessing the climate impact of ATM operations that incorporate an adequate representation of uncertainties, including CO_2 emissions, contrails, the effects on climate of ozone, methane and water vapour, and to provide concepts for climate information enabling eco-efficient aircraft trajectories;
- to investigate aviation's climate impact mitigation potential by developing robust flight-planning algorithms by incorporating ATM uncertainties from the climate impact analysis and ensemble weather forecasts;
- to identify eco-efficient aircraft trajectories, and related weather situations, that enable a reduction in both climate impact and operational costs ('win–win') by avoiding ATM inefficiencies or that largely reduce the climate impact of aviation at almost unchanged costs by avoiding extreme climate-sensitive regions ('cherry-picking');
- to provide recommendations for target stakeholders on policy actions and supporting measures to implement eco-efficient aircraft trajectories enabled by a better understanding of the climate impact of individual aircraft trajectories.

The most important achievements during 2021 were the following.

- aCCFs on the non-CO_2 effects of aviation were made available to other work packages (WPs) as prototypes. Relevant information on aCCFs was considered in order to explore different concepts to represent uncertainties resulting from, for example, weather forecasts or non-linear responses of the climate system. aCCF regions, which have a large climate impact, were analysed in terms of synoptical situation, season and altitude for 1 year of model data, building on experience from the earlier SESAR ER1 project ATM4E.

- An air traffic schedule analysis was conducted to decide on the traffic sample to be evaluated. For this purpose, a ranking of intra-European flights in 2018 was done based on the 'available seat kilometres' of the flights. The objective was to identify a reasonable and computationally manageable number of flights that are characteristic of European air traffic and that contribute to a significant portion of European air traffic. A route clustering methodology was developed and applied to the dataset to understand to what extent relevant routes can be grouped to reduce the complexity without losing accuracy. Based on that, the route clusters to be analysed were selected.
- The general settings of the experimental set-ups for the validation tasks were agreed. The EMAC (ECHAM/MESSy Atmospheric Chemistry) license was approved to use the global chemistry–climate model. The model adaptations for a cherry-picking algorithm were discussed. The first trajectory optimisation results for identifying the cherry-picking potentials were discussed. The candidate cherry-picking algorithms were tested offline.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, various activities were carried out as part of the project, including participation in relevant webinars, workshops and conferences, as well as in the SESAR Digital European Sky Awards (the project was the winner in the category 'Sustainability') and in the SESAR Innovation Days. There was also coordination with SESAR ER4 projects; in particular, there was a regular exchange of expertise with FlyATM4E and DYNCAT on environmental aspects regarding the climate impact of aviation.

FMPMet

The MET uncertainty management for flow management positions (FMPMet) project framework integrates MET forecast uncertainty information into the decision-making process for the flow management position (FMP). The FMP is an operational position located in area control centres (ACCs) that serves as an interface between ATC and the NM. The FMP monitors the level of traffic in ATC sectors, adjusts the available capacity in the case of unexpected events and coordinates possible traffic flow measures with the ACC supervisor and the NM when demand in excess of capacity is detected. The presence of convective weather poses a challenges for this task, because it makes it difficult to predict sector demand and increases complexity, thus reducing sector capacity.

The goal of FMPMet, which kicked off in 2020, is to provide the FMP with an intuitive and interpretable probabilistic assessment of the impact of convective weather on operations, up to 8 hours in advance, through probabilistic forecasts of sector demand, complexity and capacity reduction, to allow better informed decision-making. The provision of a trustworthy forecast of the future sector demand and complexity and of a reliable estimation of the impact of the convective weather in the sector capacity will support the FMP in taking anticipated, appropriate and timely tactical flow measures, which will lead to a reduction in delays and an improved passenger experience.

During the reporting period, the project developed a ConOps for flow management in severe convective weather that uses probabilistic MET information considering different look-ahead times (short term (up to 1 hour) and long term (from 1 hour to 8 hours) and different MET products (nowcast for short term and ensemble prediction system for long term).

The nowcast and ensemble prediction system forecast products, which describe the MET products, have been defined, as has the framework for the prediction of aircraft trajectories up to 8 hours considering different look-ahead times (short term (up to 1 hour) and long term (from 1 hour to 8 hours).

The project focused on the topic of forecasting multisector demands. The provision of probabilistic forecasts of sector-demand indicators that take into account convective weather, alone or in

combination with probabilistic capacity forecasts, will be useful for the FMP. During this reporting period, a methodology to determine the probability distributions of the entry and occupancy counts for individual sectors was developed.

Furthermore, an analysis was completed of sector complexity under convective weather (the provision of probabilistic forecasts of complexity metrics) and a methodology was developed to forecast the reduction of airspace capacity under convective weather, taking into account the spatial extent and topology of the weather hazard and the traffic flow direction.

HAAWAII

The project on highly automated air traffic controller workstations with AI integration (HAAWAII) aims to build on a very large collection of data, developed new sets of assistant-based speech recognition models for the complex environments of Icelandic en route operations and the London TMA. The project aims to perform proof-of-concept trials of real-life audio and surveillance data from the operations room. HAAWAII also aims to significantly enhance the validity of speech recognition models, to the extent that such models could even enable the application of pilot read-back error detection.

The main objectives of the project are to:

- exploit, using new unsupervised learning algorithms, huge numbers of unlabelled voice data to train an assistant-based speech recognition system;
- develop automatic recognition of controller–pilot data link communications for the London TMA and Isavia en route airspace;
- facilitate automatic detection of pilot read-back errors;
- achieve pre-filling of radar labels and controller–pilot data link communication messaging by means of a non-integrated application (proof of concept);
- improve ATCO staffing and rostering, as well as flow management planning and responses to changes in flow, for the London TMA by measuring and anticipating the workload from voice communications;
- ensure data privacy issues are sufficiently considered, that is, ensure that the number of anonymised data stored is minimised.

During the reporting period, the HAAWAII project delivered in line with the initial plan. The following activities were undertaken to achieve the above objectives.

- The operational concept and requirements were delivered and made available.
- The first speech recognition models for the pilot's voice were made available, which will support ANSPs during transcription. The recordings will be used for unsupervised learning and improving recognition performance, and will be used in the production of the first prototypes for read-back error detection and workload prediction.
- The first stakeholder workshop was held in the summer of 2021. The findings of HAAWAII, especially with respect to ontology updates, were shared with, for example, project PJ05 W2-97 and project PJ10 W2-96 on automatic speech recognition. Proof-of-concept trials were executed directly based on data from the operational environment of NATS and Isavia air navigation services.

The CDE plan is being executed. As part of the HAAWAII project, an event was organised with all of the relevant automatic speech recognition projects in Europe (HAAWAII, STARFiSH, solution 96 on

automatic speech recognition, solution 97 on automatic speech recognition and ATCO2) to share common information and to benefit from each other. Furthermore, the project has extended the ontology for command transcription and published the results on its website, allowing all of the automatic speech recognition projects mentioned above to benefit from these rules, developed in PJ16-04 W1 and extended by HAAWAII.

ICARUS

The integrated common altitude reference system for U-space (ICARUS) project targets the development of an altitude translation service (geodetic to/from barometric) for drones and general aviation pilots in the form of an innovative U-space service to be used in both the strategic and the tactical phases of the flight. Pilots may use the ICARUS service to obtain information about the terrain profile, distance from the ground and known ground obstacles, while keeping a common reference altitude datum.

The main objectives of ICARUS are to:

- define the technical requirements for GNSS-based altimetry;
- investigate the vertical accuracy of existing digital terrain models to be used for the avoidance of ground obstacles;
- design a U-space service for height transformation;
- define a safe common altitude reference system for drones and general aviation to enhance very low-level capacity and safety.

During the reporting period, the work of ICARUS progressed according to the initial plan and the following work towards achieving the above objectives was carried out.

- The completion of the ICARUS concept definition, including the state of the art, requirements and a gap analysis, in line with the project schedule.
- The submission of the design and architecture of the ICARUS system and services. This document sets out the overall ICARUS architecture, with a particular focus on the architecture of the proposed microservices that constitute the ICARUS contribution to the definition of U-space services. Moreover, this document outlines the operational and functional relationship between the ICARUS microservice components, the other unmanned traffic management / U-space service providers and the ATM.
- The completion of the ICARUS proof of concept and the preparation of the relative test environment to validate its functionality. The output of the work is reported under the following deliverables:
    - unmanned traffic management platform architecture
    - cockpit simulator architecture
    - D-flight GNSS augmentation interface control document and integration test report;
    - ICARUS external feasibility test and validation plan.

During the reporting period, the following CDE deliverables were completed as part of the ICARUS project:

- A roadmap and cross-fertilisation publication with concurrent U-space projects;
- Dissemination plan;
- Communication plan;

- Exploitation plan.

IMHOTEP

The integrated multimodal airport operations for efficient passenger flow management (IMHOTEP) project kicked off in June 2020. Airports of the future are expected to be multimodal connection platforms, creating conditions that allow travellers to reach their destination via the most efficient and sustainable combination of modes and that allow the airport and its surrounding region to make the best use of their resources. The goal of IMHOTEP is to develop a ConOps and a set of data analysis methods, predictive models and decision support tools that allow information-sharing, common situational awareness and real-time collaborative decision-making between airports and ground transport stakeholders.

The specific objectives of the project are the following:

- to propose a ConOps for the extension of airport collaborative decision-making to ground transport stakeholders, including local transport authorities, traffic agencies, transport operators and mobility service providers;
- to develop new data collection, analysis and fusion methods that are able to provide a comprehensive view of the door-to-door passenger trajectory through the coherent integration of different types of high-resolution passenger movement data collected from personal mobile devices and digital sensors;
- to develop predictive models and decision support tools that are able to anticipate the evolution of an airport's passenger flows within the day of operations and assess the operational impact on both airport processes and the ground transport system, with the aim of enabling real-time collaborative decision-making between airports and ground transport stakeholders and enhanced passenger information services;
- to validate the proposed concept and the newly developed methods and tools through a set of case studies (two airports with heterogeneous characteristics and serving different markets, namely Palma de Mallorca and London City airports) conducted in direct collaboration with airports, local transport authorities and transport operators.

In 2021, the project team delivered the initial version of the ConOps and the case studies to be tested in the validations. The modelling of the passenger terminal access and egress processes continued.

INVIRCAT

The focus of the INVIRCAT project is on instrument flight rule (IFR) RPAS control in airports and TMAs. It aims to provide the means of safely and efficiently integrating RPASs into existing ATC procedures and infrastructures within the TMA under IFRs. The main goals of the INVIRCAT project are the creation of a ConOps for RPASs in the TMA of airports, assessing it through simulations and drafting a set of recommendations for rule-makers and standardisation bodies.

The specific objectives are to:

- develop a complete ConOps to enable IFR RPAS integration into TMA operations;
- define technical and operational requirements for RPAS integration into TMA operations;
- investigate alternative means of integrating airport-located remote pilot stations for the control of RPASs in a TMA;
- analyse the accommodation and integration with U-space of the following:

- a risk-based method for determining separation minima;
- a method for calculating conflict frequencies;
- a method for calculating the collision risk in a conflict;
- a methodology for generating and simulating UAS representative trajectories based on basic trajectory patterns.

During the reporting period, the work of INVIRCAT progressed according to the initial plan. The following work towards achieving the objectives was carried out.

- With the publication of deliverable D2.3, the initial ConOps, the first major step towards the definition of the final ConOps in March 2022 has been accomplished. The initial ConOps will be used as a baseline for the project's validation efforts through human-in-the-loop simulations and further assessment through the Advisory Board. The SESAR JU positively assessed and approved the document with few suggestions for possible enhancements to be considered in the final version of the ConOps, which will be deliverable D2.4. The first deliverable discussing technical and operational requirements (D2.5, the preliminary requirements definition) was submitted in October 2021. These requirements will feed into a second document, deliverable D4.2 (the final operational and technical requirements definition), making use of the simulation validation results.
- During the state-of-the-art research (deliverable D2.1) and the production of the initial ConOps (deliverable D2.3), three different technical architectures for communication and command and control links were identified. The influence of signal delay on flight procedures and operations was assessed within the use case descriptions (deliverable D2.2) and will be validated in the upcoming simulation scenarios. In addition, the role of automatic take-off and landing systems and the usability of handover procedures between remote pilots who are located at different remote pilot stations will be explored in the validation scenarios. Requirements and recommendations were submitted in deliverable D2.5 in October 2021.
- In coordination with the SESAR JU, the project consortium decided to focus on the project's scope, namely the integration of large remotely piloted aircraft in the TMA that are capable of flying under IFRs. Therefore, the U-space considerations played only a minor role in the development of the ConOps and the project. Nevertheless, a dedicated chapter in the initial ConOps discusses the possible use of U-space services for remotely piloted IFR aircraft. In addition, the project supports the U-space ConOps coordination cell in the concept development.

ISOBAR

The main objective of the ISOBAR project, which focuses on AI solutions to MET-based demand–capacity imbalances for network operations planning, is to improve network performance and achieve mutual benefits though AI-enabled collaborative decision-making. ISOBAR will focus on preventing and deconflicting chaotic situations in the pre-tactical phase and continuous plan readjustment. Decision-making will be triggered by high or very high convective area risk prediction and a collaborative process with a continuous reassessment and refinement, taking advantage of the digitalisation of the support tools.

The project aims to integrate enhanced convective weather forecasts in order to predict imbalances between capacity and demand and to employ AI to prescribe mitigation measures at local and network levels.

Network performance is very sensitive to weather conditions, the prediction of which is notoriously uncertain. In addition, current air traffic flow and capacity management (ATFCM) operations have not been systematically evaluated. Taken together, these two factors mean that network performance is highly dependent on the skill and experience of human operators. The ISOBAR project, which kicked

off in 2020, aims to address these challenges by contributing to an AI-based network operations plan that includes enhanced weather prediction, tailored to ATFCM and ATM, demand–capacity imbalance characterisation and the ability to mitigate demand–capacity imbalance.

During the reporting period, the project team started to develop the operational and simulation framework for collaborative ATFCM considering convective weather scenarios. The first operational framework task, which provides the requirements specification, covering functional, non-functional and interface requirements related to ISOBAR, was completed. In addition, a majority of the work of describing the concepts of AI solutions to MET-based demand–capacity imbalances for network operation planning was done.

The identification of the capacity shortfalls due to weather in the airspace system for different time horizons was initiated. An ML demand prediction model, which presents the works and intermediate achievements provided through the AU preference AI module, was completed and a hotspot detection library, based on demand and capacity characterisation, was produced.

In the area of incorporating AI into DCB, the project's aim is to develop a solution to the DCB hotspot mitigation problem using AI techniques. The development activities for this solution were completed.

The creation of the ISOBAR training and testing datasets was also completed. Moreover, the project team developed an HMI showcase to disseminate the ISOBAR concepts, mechanisms and added value to internal and external audiences. The prototype developed demonstrates new functionalities linked to weather prediction and its impact on air traffic capacity.

The technical performance of the ISOBAR AI models was evaluated to demonstrate their potential usability and the operational benefits of the ISOBAR solution.

ITACA

The incentivising technology adoption for accelerating change in ATM (ITACA) project aims to accelerate the development, adoption and deployment of new technologies in ATM. ITACA will develop a new set of methodologies and tools enabling the rigorous and comprehensive assessment of policies and regulations. This will result in the development of a better understanding of barriers to change in ATM, amplifying the uptake of new technologies within ATM and accelerating the achievement of the ATM master plan performance ambitions enabled by SESAR solutions.

ITACA kicked off in May 2020. The project objectives are to:

- identify the main drivers of and barriers to technological change in ATM and devise a set of policy measures and regulatory changes with the potential to lower such barriers and incentivise faster technology upgrade;
- develop an agent-based model of the R&I life cycle that allows the representation of complex decisions and interactions between ATM stakeholders and their impact on the development and implementation of new technologies;
- validate the behavioural assumptions of the agent-based model through a set of participatory simulation experiments involving the direct participation of ATM stakeholders;
- demonstrate and evaluate the potential of the newly developed methods and tools through a set of policy assessment exercises that will analyse the impact of a variety of policies and regulatory changes aimed at accelerating technology change in ATM, with a particular focus on the distributional effects of the proposed policies across ATM stakeholders and society at large;

- consolidate the methods and tools delivered by and the lessons learnt through the project into a coherent policy assessment framework and a set of policy recommendations, and provide guidelines for the future maintenance, evolution and use of the proposed framework.

During 2021, the project developed a set of economic models that integrated the objectives of the different stakeholders bearing the costs and benefits of the investments in ATM technologies, taking into account the institutional and regulatory framework and the characteristics of the technologies. With the help of the assessment framework that is currently being developed, during the second half of the project ITACA will provide recommendations on how to facilitate technological change in ATM.

In particular, the project has produced deliverable D2.1 (the identification of levers for and barriers to the adoption of new ATM technologies), which includes a qualitative analysis of levers and barriers, an economic model to analyse the uptake of certain ATM technologies based on the potential efficiency gains by both ANSPs and airlines and, finally, the definition of a set of promising policy and regulatory measures based on both the initial qualitative assessment and the economic modelling.

The project also delivered the experimental plan for the ITACA simulation model, which is aimed at defining the validation activities to ensure the applicability of the ITACA simulation model for benchmarking policy measures.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, various activities were performed as part of the project, including the presentation of papers and the organisation of the first ITACA stakeholder workshop.

MAHALO

The modern ATM via human/automation learning optimisation (MAHALO) project will develop a prototype ML modelling system, coupled to an enhanced ecological user interface, and will empirically explore the effects of ML conformance and transparency, as well as contextual factors (e.g. traffic complexity), on human and ATM system performance. The objective is not only to demonstrate ML conflict detection and resolution capability, but is also to create an empirically derived framework and guidelines for how to develop advanced future AI, both in ATM and in other relevant domains.

The MAHALO project kicked off in June 2020. The objectives of the project are to:

- create and demonstrate a ML system comprising layered deep learning and reinforcement models that are trained on controller performance, control strategies and eye scan data, and that learn to resolve ATC conflicts;
- develop both a control model of ATC and an associated ecological user interface that (when operating in automated mode) augments the typical plan view display with machine intent and decision selection rationale (to help foster transparency);
- experimentally evaluate, using human-in-the-loop simulations, the relative impact of conformance and the transparency of advanced AI in terms of, for example, controller trust, acceptance, workload and human/machine performance, and how these are affected by factors such as air traffic complexity and degraded mode operations;
- define a framework to guide the development of future AI systems, including guidance on the effects of conformance, transparency, complexity and non-nominal (degraded mode) conditions.

During 2021, the following work was carried out to fulfil these objectives.

- The definition of the MAHALO operational concept, which provides the foundation for the subsequent conflict detection and resolution specifications, ML model development and integration, interface design, human-in-the-loop simulation, and analysis.
- An assessment of the state of the art on human performance and ML techniques, the design of a hybrid model using ML components enabling human–automation collaboration in conflict resolution scenarios, and the conceptualisation and training of two distinct ML models for supporting conflict resolution, the conformal / human-based approach and a transparent / optimal machine reasoning approach. The ML models developed will be central for the upcoming human-in-the-loop experiments in which the project will assess and compare the different approaches to support automation.
- The development of an initial prototype of the MAHALO ecological user interface. The ecological user interface consists of several visual representations of traffic conflict states that allow both human air traffic controllers and automated ML agents to perform conflict detection and resolution activities.
- The integration of the ecological user interface prototype into the SectorX Java-based ATC simulator to be used by controllers as a decision-support tool and as a way to monitor automation activities.
- The delivery of the ecological user interface validation report. A first dry-run simulation (SIM1) was conducted with students to test the viability of the experimental set-up and the two ML models in October 2021.
- The conducting of the pre-test experiment of SIM2A (the first round of data collection that will serve as the input for the main experiments with the same participants) in Italy with 20 real ATCOs in December 2021.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, as part of the project, presentations were delivered at relevant workshops and conferences, such as the SESAR Innovation Days and the AI and ML coordination workshop in March 2021. An Advisory Board was also set up, involving EUROCONTROL, ATCO associations, ANSPs, academics and the TAPAS, AISA and ARTIMATION ER4 projects. Finally, three scientific publications were published and are available in green open access.

Metropolis 2

The Metropolis 2 project aims to provide the fundamentals for concrete solutions for U-space advanced (U3) and full (U4) services that are needed to enable high-density urban aerial operations, with a unified approach to the following U-space services: strategic deconfliction, tactical deconfliction and dynamic capacity management. The main objective of the project is to develop a unified approach to airspace rules that takes account of flight planning and separation management approaches and to demonstrate these principles in a real-world validation exercise. It will build upon the results of the current U-space projects, the first Metropolis project and established separation algorithms. The SESAR JU kicked off Metropolis 2 in November 2020.

The specific objectives of Metropolis 2 are to:

- extend the segmentation and alignment principles of geovectoring to an operational concept for airspace rules to enable high-capacity urban airspace;
- develop a unified design approach to the management of traffic in high-density urban airspace on all timescales;

- determine the benefits and drawbacks of separation management paradigms with different approaches to who acts as separator (the drone, the U-space service or a combination thereof) and different combinations of procedural and tactical separation;
- investigate the priority-based integration of manned aviation in urban (drone-only) airspace that robustly integrates with airspace rules and separation provision, and demonstrate the final concept coming out of the Metropolis 2 project in a real-world validation.

During the reporting period, the following work towards the achievement of the above objectives of Metropolis 2 was carried out.

- Scenarios were designed as a combination of different levels of each independent variable.
- Three competing concepts for airspace rules, DCB and separation management were designed, taking ground, hybrid and airborne perspectives.
- Common technologies for defining all concepts were developed. The concept work resulted in two deliverables: D4.1 (a concept design report) and D4.2 (concept implementations).
- (New) Drone performance models were developed, and the integration of topological data and visuals started in Q1 2021 and was completed at the end of Q3 2021. Adaptations of the autopilot to enable drone-specific behaviour started in Q3 2021 and were completed at the end of Q4 2021. Performance optimisations of the simulator started in Q4 2021. Improvements in this area are expected to continue until all three concepts are completely integrated into the final simulation, and the running of the test scenarios has begun. Out of this work, the project produced two deliverables: D5.1 (a simulation platform update report) and D5.2 (simulation trials data). The validation activities were also started and the results will be reported in the next reporting period through two deliverables: D6.1 (validation trials data) and D6.2 (a validation report), both due at the end of October 2022.

As part of the project, a CDE plan was also developed via two deliverables – D7.1 (website and social media presence) and D7.2 (a data management plan) – both of which were approved by the SESAR JU.

Modus

The **Modus** project focuses on modelling and assessing the role of air transport in an integrated, intermodal transport system. It analyses the performance of the overall transport system by considering the entire door-to-door journey holistically. The project identifies future drivers of passenger demand and supply and assesses the impact on airside and landside processes and capacities. Based on these analyses, potential solutions to meet high-level European transport objectives are proposed.

The Modus project kicked off in June 2020 and has the following objectives:

- to understand how ATM and air transport can help improve passengers' intermodal journeys, with a view to enhancing the performance of the transport system as a whole; this requires the identification, by means of a modal choice analysis, of the drivers of future transport demand and supply in order to better understand the factors that influence the allocation of demand across different transport modes in the short-haul market;
- to develop scenarios and passenger archetypes that take account of future developments that the European (air) transport system might need to address, which will be modelled to assess both the landside and the airside impacts;
- to explore and model the connection between and interdependence of ATM / air transport and other transport modes, with a special focus on the interplay between short- and medium-haul

air and rail connections, integrating different passenger archetypes, passenger mobility metrics and performance indicators;

- to identify the main barriers to achieving European (air) mobility goals and how air transport can evolve by efficiently connecting information and services with other transport modes to achieve the 4 hours door-to-door goal and a seamless journey experience for passengers.

During 2021, the following deliverables were produced to fulfil these objectives:

- deliverable D3.1 (a modal choice analysis and expert assessment), which identifies the future drivers of supply and demand for a multimodal European transport system, complemented by an expert survey, providing the basis for the modal choice analysis; as part of this deliverable, Modus scenarios and performance and connectivity indicators were identified and analysed;
- deliverable D4.1 (the interface to the modal choice model), which describes the methodology for translating the output of the modal choice model into individual passenger itineraries that will be used by the mobility models; as part of this deliverable, the data requirements and processing needs for creating valid input for the Modus models (the flight-centred airside model RNEST, the passenger-centric airside model Mercury, and the landside door-to-door model) were specified;
- deliverable D5.1 (Modus use cases), which describes the door-to-door traveller journey in use cases, with a particular focus on the cooperation and substitution potential between air and rail transport;
- deliverable D3.2 (demand and supply scenarios and performance indicators), which establishes multimodal scenarios for future European mobility and identifies KPIs for multimodal transport.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, the project was presented at relevant workshops and conferences. The article 'Analytical models for CO_2 emissions and travel time for short- to medium-haul flights considering available seats. Sustainability MDPI' was published.

NewSense

The NewSense project is an evaluation of the 5G network and millimetre wave (mmW) radar sensors to enhance surveillance of the airport surface. The project started in November 2020 and aims to improve the safety and efficiency of operations, primarily in secondary airports, by developing innovative low-cost surface surveillance solutions allowing the implementation of affordable advanced surface movement guidance and control systems (A-SMGCSs).

It also aims to develop gap-filling solutions that can be deployed at larger airports to address current system limitations, such as coverage issues, to extend ATCOs' situational awareness in the parking and apron areas, and to enable an increase in automation levels through, for example, automated detection of airport collaborative decision-making milestones events.

The objectives of the project are to:

- design a 5G signal-based surveillance function for use in A-SMGCSs, including a three-dimensional (3D) vector antenna, source of angle of arrival estimation, a 5G positioning function identifying cooperative targets and calculating their position using the angle of arrival and estimating the time of arrival from their transmitted 5G radio frequency signals, and a radar-like system relying on 5G signals to calculate all targets' position from the angle of arrival and time of arrival of reflected 5G base station radio frequency signals;

- evaluate low-cost mmW radar for use in A-SMGCSs combined with AI to recognise target types from reflected mmW radar signals;
- propose an initial system design for the use of these solutions in A-SMGCSs.

The project has undertaken an operational, security and safety preliminary requirements analysis and produced a concept report. In addition, initial technical assessments were undertaken in line with the project plan in 2021.

NOSTROMO

The activities of the NOSTROMO project in 2021 are described in Section I.4.1.1.

SAFELAND

The focus of the SAFELAND project is on safe landing through enhanced ground support. It is intended to improve safety in the event of single pilot incapacitation, through an improved ATM-centred concept, offering ground support for the management of the flight until it lands safely. SAFELAND focuses on the ground side and, in particular, on the potential role of ATM in managing the transition from a single-pilot-operated flight to operations in which the on-board pilot is reduced/absent for landing.

The specific project objectives are to:

- define a SAFELAND operational concept, with the related ground support procedures, for the management of incapacitation of a single pilot until safe landing, focused on the ATM perspective;
- analyse the different possible implementations of the SAFELAND concept, including, for example, the allocation of the remote piloting functions, the presence and location of the ground remote pilot, and the level of automation;
- evaluate the SAFELAND concept and procedures with the support of different stakeholders and with a variety of exercises, including simulations;
- identify the functionalities of possible new additional systems that could help the ground personnel (e.g. the ATCO or remote pilot) in supporting flight management;
- exchange information and results with complementary projects in Clean Sky and SESAR, and analyse the compatibility of their operational concepts with the SAFELAND operational concept.

During the reporting period, work progressed according to the initial plan. The following work towards the achievement of the above objectives was carried out.

- The SAFELAND ConOp, proposing a conceptual framework to manage in-flight incapacitation in single-pilot operations, was developed and described. The concept addresses the handover from a single-piloted flight operation to a remotely piloted flight operation, by taking ATM aspects into account. The SAFELAND concept development process concluded with the submission of deliverable D1.4, the final concept.
- During the development of the SAFELAND ConOp, several implementation options were taken into consideration. Such implementations differed, for example, in the allocation of the piloting functions, in the level of automation, and in the roles and responsibilities foreseen for the different actors involved. The result of this work was submitted in deliverables D1.2 (the initial concept) and D1.4 (the final concept). A dedicated deliverable (D1.3, legal, regulatory and economy constraints) analysed the legal, regulatory and economic implications of the different implementation options, identifying points of strength and possible showstoppers.

- Several implementation options were evaluated with the support of the stakeholders of the Advisory Board. The inputs collected covered different categories, such as safety; security; human performance; operational, legal and regulatory aspects; and technical feasibility. Feedback and recommendations from the Advisory Board were used in the refinement of the final SAFELAND concept. Details of the evaluation activities performed are described in two deliverables that were submitted and approved by the SESAR JU (D3.1, the evaluation plan, and D3.2, the preliminary evaluation results).
- High-level functionalities and architecture of some new additional systems supporting the ground personnel in the management of the incapacitated flight were proposed. The functionalities of the new additional systems will subsequently be refined with the support of simulation results and Advisory Board feedback.
- The SAFELAND project established collaborations with other ongoing research projects dealing with the single pilot operation concept, RPASs, safety and security (INVIRCAT, URClearED, PJ13 and CORUS-XUAM). This allowed project plans and research results to be shared in order to minimise potential overlap of work, uncover collaboration opportunities and ensure the compatibility of the project solutions. Another fruitful collaboration was established with the SAFEMODE project, a H2020 R&I action dealing with safety enhancement in the maritime and aviation domain, in order to explore and validate common solutions to pilot incapacitation.

SafeOPS

The SafeOPS project is investigating how to integrate data-driven and automation-based decision intelligence into the current ATM system. ML technologies have the ability to analyse vast numbers of diverse data (usually coming from different sources) to extract patterns. This hidden knowledge can be used to identify/predict safety risks or performance inefficiencies and, in doing so, offer support to controllers in their decision-making. By processing years of operational data (i.e. years of practice), AI can also support controllers' training needs and subsequent performance in the operational room.

The SafeOPS project was kicked off in January 2021. The objective of the project is to design and evaluate a prototype risk management system for identifying and actively managing probabilistic information within an operational risk framework. The overall research goal is to move 'from prediction to decision' with the following elements:

- a common operational concept of probabilistic performance indicators for certain safety scenarios for which AI works;
- a methodology for operational risk analysis that can support risk assessment with richer probabilistic information;
- a dissemination forum that will engage key operational stakeholders to adopt and implement richer digitalisation tools.

During 2021, the following work was carried out to fulfil these objectives.

- The SafeOPS concept was developed through the organisation of dedicated workshops with ATCOs and researchers. This allowed the development and understanding of current strategies applied in go-around handling, current tools and potential complex situations. It also resulted in the development of concepts and use cases for data-driven go-around predictions for decision support. Finally, scenarios for investigating the impact of the SafeOPS concept on the safety and resilience of ATM were developed.
- The SafeOPS concept was validated through the development of an experimental plan that also assessed its effects on the safety and resilience of ATM.

- The human factors involved in providing probabilistic information to ATCOs in go-around handling situations were investigated.
- Operational data (automatic dependent surveillance broadcast (ADS-B) and quick access recorder / flight data monitoring data) were collected and used to train data-driven decision support tools integrated into the DataBeacon development platform.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, the project was presented at relevant workshops and events, such as the SESAR JU coordinated ER4 automation workshops and the SESAR Innovation Days in 2021.

SIMBAD

The SIMBAD project, which combines simulation models and big data analytics for ATM performance analysis, aims to develop and evaluate a set of ML approaches aimed at providing state-of-the-art ATM microsimulation models with the level of reliability, tractability and interpretability required to effectively support performance evaluation at ECAC level. The project will demonstrate and evaluate the newly developed methods and tools through a set of case studies.

The SIMBAD project kicked off in January 2021. The objectives of the project are as follows.

- To explore the use of ML techniques for the modelling of trajectories and the estimation of hidden variables in historical air traffic data. Particular attention will be paid to the estimation of variables related to AUs' preferences and behaviour (e.g. airline cost functions), which are one of the major unknowns when assessing the performance benefits actually delivered by a certain ATM concept or solution.
- To develop new ML algorithms for traffic pattern classification. Given the complexity of large-scale air traffic simulations, running simulation models for every day of the year is usually prohibitive. On the other hand, limiting simulations to one day or a few particular days may not be representative of the impact of a certain operational improvement under other scenarios. SIMBAD will investigate how different clustering and ML classification techniques can be used to identify a representative set of demand patterns that allows a comprehensive impact assessment of new SESAR solutions at ECAC level to be undertaken.
- To enable a more efficient exploration of the input–output space of complex ATM simulation models through the use of active learning metamodelling. Given the computational cost of realistic air traffic simulations, a goal when exploring the simulation space should be to pick only the most informative instances. SIMBAD will explore how active learning can be used to translate a complex simulation model into a performance metamodel, improving computational tractability and the interpretability of results.
- To demonstrate and evaluate the newly developed techniques in order to assess their maturity, derive recommendations on how to apply them to ATM performance assessment, and propose a roadmap for the transition of the project results to the next stages of the R&I cycle. To this end, two case studies will be developed in which the proposed techniques will be integrated with existing state-of-the-art ATM simulation tools and used to analyse a variety of ATM performance problems.

During 2021, the following work was carried out to fulfil these objectives:

- gathering data for and assessing the different datasets that will be used throughout the project, the selection and definition of the SIMBAD case studies, and the identification of relevant hidden variables related to AUs;

- the design, implementation, training and testing of two imitation learning methods for data-driven trajectory estimation and of ML algorithms for the estimation of hidden variables;
- the selection and definition of the most relevant traffic features and KPIs to find the traffic patterns for each case study defined;
- the definition of the geographical and temporal scales to be studied for traffic pattern identification;
- the definition and implementation of a simulation metamodel for DYNAMO, and the selection and implementation of the active learning framework for training the DYNAMO metamodel.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, the following additional activities were performed: the organisation of regular meetings and workshops with the SIMBAD Advisory Board, involving EUROCONTROL, CANSO, Direction des Services de la Navigation Aérienne (DSNA; France's ANSP) and Skyguide (the Swiss ANSP), as well as academia; participation in the SESAR Innovation Days in 2021; and the publication of the scientific article 'Visual analytics for human-centred machine learning' in *IEEE Computer Graphics and Applications*.

SINAPSE

The SINAPSE project (focusing on software-defined networking (SDN) architecture augmented with AI to improve aeronautical communications performance, security and efficiency) started in May 2020 and aims to propose an intelligent and secure aeronautical data link communications network architecture design based on the SDN architecture model augmented with AI to predict and prevent safety services outages, to optimise available network resources and to implement cybersecurity functions protecting the network against digital attacks.

The project has the following objectives:

- To design a solution suitable for ATM needs. This includes the identification of relevant ATM operational, performance, safety and security requirements. In addition, it is intended to propose a consolidated SDN design, augmented with AI, that complies with these requirements.
- To guarantee ATC data link service performance by designing and prototyping AI applications to anticipate and prevent service issues and outages. In addition, it is intended to design an SDN-based aeronautical network integrating the ML application.
- To optimise network resources through designing and prototyping an AI application to support quality of service predictions to optimise network resources. There are also plans to design an SDN-based aeronautical network integrating the ML application.
- To implement cybersecurity mechanisms to detect and prevent digital attacks. This includes designing and prototyping an AI application to provide cybersecurity against prevalent network threats. Threats violating network confidentiality and integrity will also be covered, along with a security architecture for the SDN-based aeronautical network integrating the AI application.

The project has completed the operational, security and safety preliminary safety requirements analysis, along with a number of technical deliverables on ATS data link performance and network optimisation linked to AI.

SINOPTICA

The satellite-borne and in situ observations to predict the initiation of convection for ATM (SINOPTICA) project aims to explore the potential of assimilating remote sensing (Earth observation-derived and ground-based radar) and GNSS-derived datasets and in situ weather station data into very high-

resolution, very short-range numerical weather forecasts to provide improved predictions of extreme weather events for the benefit of ATM operations.

This will be done by setting up a continuously updated database of remote sensing-derived, GNSS-derived and in situ weather station observations, in combination with an automated assimilation system to feed a numerical weather model (NWM). The usefulness of deploying dedicated networks of sensors to monitor atmospheric variables in the vicinity of ATM hotspots such as airports will also be investigated. The added value of SINOPTICA tools and their incorporation into ATM procedures and decisional support systems will be evaluated with a particular focus on the tactical phases of flight arrivals and departures.

SINOPTICA kicked off in July 2020 with the following objectives:

- to provide access to satellite- and ground-based weather data for different study regions in Europe;
- to provide access to ground-based weather radar data for different study regions in Europe;
- to develop a near real-time data assimilation system into a high-resolution NWM;
- to investigate the usefulness of the augmented NWM forecasts for ATM activities;
- to integrate the augmented NWM forecasts into ATM procedures and decision support systems;
- to develop a near real-time ground-based GNSS water vapour monitoring system;
- to investigate the usefulness of deploying dedicated cost-effective GNSS stations near airports;
- to provide access to GNSS radio occultation products over the study region in Europe.

During 2021, the following work was carried out to fulfil these objectives.

- The development of a near real-time ground-based GNSS water vapour monitoring system.
- The development of a near real-time data assimilation system into a high-resolution NWM.
- The completion of deliverable D4.1 (an operation concept description and user requirements for adverse weather controller support) defining the operation concept, the user requirements and the functionalities of the systems required for supporting the ACC and TMA air traffic controllers for guiding aircraft and pilots in adverse weather situations. The main focus of this concept is a radar display extension to visualise actual and forecasted weather development and the automatic diversion generation of an extended arrivals manager (E-AMAN).
- The completion of deliverable D4.2 (an evaluation methodology and plan) describing the validation methodology. The expected benefits of the integration of convective weather information into E-AMAN systems will be assessed by ATM experts.
- The completion of deliverable D5.1 (a report about selection) describing four severe MET events that will serve as the operational scenarios to be addressed during validation activities. These events affected TMA activities at Italian airports during 2019/2020.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, the project provided presentations at relevant workshops and conferences.

SlotMachine

The SlotMachine project, which kicked off in 2020, will focus on user-driven optimisation in the allocation of ATFM slots to flights. ATFM slots are allocated times of departure, which are issued by EUROCONTROL's NM to regulate traffic in congested areas of airspace. Until now, only simple

exchanges between two flights from the same airline company have been possible. These are a helpful way for airlines to prioritise expensive flights in order to minimise delays and keep costs down.

Flight exchanges between different airlines are currently limited owing to the confidentiality surrounding flight cost structures, which may vary for any number of reasons, including the provisioning of connecting flights for passengers and the work-time restrictions of crew members. This is where the SlotMachine project comes in. By using blockchain technology and a secure multi-party computation, the project aims to extend the existing UDPP solution currently in development in SESAR 2020 to allow more flexible flight sequences with no need for the disclosure of any confidential information.

This technology allows secure, auditable transactions without the need for a central broker, whereby stakeholders are able to enter flight sequence transactions without disclosing information to other users. By demonstrating the feasibility of a privacy-preserving platform for exchanging ATFM slots, the foundation can be laid for the development of a product that will be an essential element in the aviation industry in the future. It is also expected to lead to a better use of existing resources at airports, higher efficiency of airlines, lower emissions and shorter delays for passengers.

During the reporting period, the initial concept of a privacy-friendly UDPP system was developed. The project team performed literature studies and reviewed the current processes and systems in place for slot management. Workshops and interviews with various stakeholders were also used to identify the initial requirements. The requirement specification, the system design and the business concept definition tasks were all also completed during the reporting period.

A secure slot-swapping system in which private airline data are kept secret, even during the identification of optimal swaps, was investigated. The ability to participate in slot swapping without revealing sensitive data is seen as a unique selling point for SlotMachine and makes it possible for many airlines to participate. The first specification of this task has been completed.

Moreover, the development of a user-driven slot swapping system (SlotSwapping) that keeps private inputs by AUs hidden under the assumption of an honest but curious provider has begun.

Using an evolutionary algorithm, the SlotSwapping system will determine slot swaps based on constraints on non-private data (e.g. aircraft type and airport capacity) and on private data delivered by the AU (e.g. delay target and costs). The SlotSwapping system will first find potential reconfigurations of slots and flights by solving a constraint satisfaction problem regarding non-private data. The PrivacyEngine developed will then rank potential reconfigurations according to a fitness value computed regarding the private data. By altering the reconfigurations based on the PrivacyEngine's output, the SlotSwapping system will iteratively improve the solutions.

START

The START project addresses TBOs, aiming to develop a stable and resilient ATM by integrating robust airline operations into the network. One of the key enablers of TBOs is the automated updating of trajectories in reaction to developing uncertainties. However, a high frequency of updates and modifications leads to degraded system stability. The overall goal of START, which kicked off in 2020, is to develop, implement and validate optimisation algorithms for robust airline operations that result in stable and resilient ATM performance even in disturbed scenarios.

START's goal will be reached by a suitable combination of methods from applied mathematics (mathematical optimisation, optimisation under uncertainty, AI and data science) and algorithm design. Furthermore, insight into the uncertainties relevant in TBO systems will be gained through simulations. The main focus of the project is the optimisation of conventional traffic situations while considering disruptive weather events such as thunderstorms.

During the reporting period, the models and processes required to capture the influence of the microlevel uncertainties that are present in the development of the aircraft trajectory were implemented. Furthermore, a data-driven approximate ATM network model based on the historical data, enabling simulation and analysis of uncertainty and delay propagation, was developed. In addition, a description was completed of the ConOps and the simulation environment for the development of an AI algorithm capable of generating a set of pan-European robust trajectories that make the European ATM system resilient when facing these relevant uncertainties. Finally, the validation metrics were defined.

SYN AIR

The synergies between transport modes and air transportation (SYN AIR) project aims to generate common goals for transport service providers (TSPs) that will justify data-sharing while helping the user to execute a seamless door-to-door journey. SYN AIR will generate customer door-to-door journeys and will analyse how those journeys can be facilitated through improved planning and operations activities (following the ATFCM phases: strategic, pre-tactical and tactical), powered by data-sharing.

SYN AIR kicked off in January 2021 with the following specific objectives:

- to determine the willingness of TSPs to collaborate and share data by examining and determining planning and operational goals;
- to develop a data flow model for TSPs of all transport modes and execute an impact assessment of data-sharing with the goal of developing quantifiable metrics on data-sharing;
- to create a business process model for the design and implementation of the smart contracts framework;
- to explore if data collected from travel companion apps can enrich the data of TSPs in the strategic, pre-tactical and tactical phases, thereby enabling informed decision-making during the creation and execution of smart contracts.

During 2021, the following work was carried out to fulfil these objectives:

- a survey was launched in Italy, Greece, Serbia, Spain and other EU Member States; 2 200 valid answers were collected and the survey results were analysed, leading to 23 validated customer journeys;
- bibliographical research was conducted on the network management strategies of different modes and a sensitivity analysis was performed;
- deep interviews were held with TSPs of different transport means (i.e. public transport authorities, transport on-demand providers, taxi services and airlines) and sustainable mobility stakeholders of different EU Member States;
- the stakeholders and the datasets generated per mode were defined, and data flow diagrams of multimodal chains were created to identify the data that are critical for sharing among TSPs of different modes for promoting coordinated transport and single ticketing concepts;
- a state of preference survey was designed and conducted based on ‘what if’ scenarios and by determining metrics related to the impact of miscommunication or good communication between TSPs;

- more than 100 different travel companion apps were analysed, clustering them based on their functionalities and per mode, in order to investigate how the smart contract framework can have an impact on workflow;
- three initial data governance models concepts were developed that represented the potential solution of a smart contract framework digital platform; these were presented to the stakeholders of SYN AIR during the first stakeholders' workshop.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, project representatives participated in relevant workshops such as the SESAR workshop on multimodality. A paper was also submitted to the Transport Support Arena 2022 Conference on the sustainability issue.

TAPAS

The project towards an automated and explainable ATM system (TAPAS) aims to explore highly automated AI-based scenarios through analysis and experimental activities applying XAI and visual analytics, in order to derive general principles of transparency. It is hoped this will pave the way for the application of AI technologies in ATM environments, enabling higher levels of automation.

The TAPAS project kicked off in June 2020. The objectives of the project are to:

- describe and analyse in detail two operational cases, ATFCM (pre-tactical) and conflict detection and resolution in the ATC working position (tactical), and considering in each case automation levels 1–3 according of the SESAR model, which involve various types of interaction between the system and the human operator;
- develop an XAI method that addresses the requirements of both operational cases and that focuses on the needs of operators concerning the quality and transparency of solutions;
- apply visual analytics techniques to assess and enhance the explainability of AI/ML systems in ATM;
- run experiments that assess the applicability of XAI methods in the various levels of automation considered, exploring different forms of interaction and information exchange;
- draw conclusions and develop general principles and recommendations based on these experimental results and analysis that will enable the implementation of XAI methods in higher levels of automation in ATM.

During 2021, the following work was carried out to fulfil these objectives:

- the development of TAPAS ATFCM and conflict detection and resolution use cases, related functional requirements and a functional roadmap for the allocation of tasks between the human and the machine for the different levels of automation (levels 1–3) within the project scope;
- the specification of the transparency and explainability requirements for both the ATFCM and conflict detection and resolution use cases for the different levels of automation;
- an analysis of the state of the art of XAI (transparent AI) methodologies; the development and delivery of the ATFCM use case system prototype, integrating XAI (transparent AI), visualisation and visual analytics; and the delivery of datasets for training and testing the AI/ML methods;
- the preparation of the intermediate version of the principles for transparency framework, including a specific methodology to apply in XAI environments;

- the delivery of a validation plan for TAPAS ATFCM and conflict detection and resolution use case validation experiments, the execution of ATFCM use case validation activities through RTS involving ENAIRE FMPs, and the delivery of a final validation report.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, the project was presented at relevant workshops and conferences.

TRANSIT

The TRANSIT project focuses on travel information management for seamless intermodal transport. It aims to develop a set of multimodal KPIs, mobility data analysis methods and transport simulation tools that allow the evaluation of the impact of innovative intermodal transport solutions on the quality, efficiency and resilience of the door-to-door passenger journey.

During 2021, the work focused on:

- proposing a set of new intermodal concepts and passenger information services based on information-sharing and coordinated decision-making between air transport and other transport modes;
- defining a new set of multimodal indicators and metrics that extend existing performance frameworks to take into account the nature of trips with multiple legs and to capture the contribution of each stage of a trip to different performance areas;
- gathering and assessing the different datasets that will be used throughout the project, including anonymised mobile network data, more conventional data on transport supply (transport network, schedule of transport services, etc.) and demand (e.g. travel surveys);
- developing new algorithms for passenger and trip characterisation through the analysis of anonymised mobile network data and their fusion with other data sources, such as ticketing data and travel surveys;
- optimising algorithms required to simulate the proposed intermodal solutions, including arrival and departure management and timetable synchronisation;
- specifying and developing the modelling framework that will be used in the project.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, various activities were carried out as part of the project, such as the setting up of an Advisory Board, involving different stakeholders (Vueling Airlines, RENFE, the UK Department for Transport and academic experts). Project representatives also participated at relevant workshops and delivered a presentation to the International Finance Corporation-World Bank, the Advisory Council for Aviation Research and Innovation in Europe (ACARE) Working Group 1, International Air Transport Association (IATA) and Shift2Rail.

Finally, scientific publications have been prepared thanks to this project. The paper ‘Enhanced passenger characterisation through the fusion of mobile phone records and airport survey’ was published in the *Journal of Air Transport Management*; the paper ‘Airport accessibility surveys and mobile phone records data fusion for the analysis of air travel behaviour’ was accepted for presentation at the International Conference on Transport Survey Methods, which will take place in Lisbon in 2022; and two publications with the titles ‘Flight rescheduling to improve passenger journey during airport access mode disruptions’ and ‘Flight-train timetable synchronization at a hub airport for a seamless passenger journey’ were submitted to the International Conference on Research in Air Transportation.

URClearED

The focus of the URClearED project is on a unified integrated remain-well-clear (RWC) concept in airspace D–G classes. This project aims to support studies of RWC functionalities by defining and analysing operational scenarios and then assessing the requirements set out and assumptions made in current standards and applicable documents, thus paving the way for future industrial-level activities.

The specific objectives of the project are to:

- define a set of operational scenarios of interest for the integration of an IFR RPAS into class D–G airspaces, taking into account the assumptions made and requirements set out in existing documents and projects;
- develop an RWC algorithm to support the evaluation of assumptions and requirements;
- integrate the RWC algorithm developed for the evaluation of a detect and avoid (DAA) system;
- define a test plan for verification activities and conduct both fast-time simulations and real-time human-in-the-loop validations;
- assess DAA system performance requirements;
- analyse procedures for the management of RPASs flying in airspace classesD–G.

During the reporting period, the work progressed according to the initial plan. The following work towards the achievement of the objectives was carried out.

- The operational scenarios were defined and reported in deliverable D2.1. The first iteration of the definition of requirements was completed and included in deliverable D2.2.
- The requirements were in the process of being implemented. The implementation was based on a fully developed DAA system already existing at Centro Italiano Ricerche Aerospaziali (CIRA), which was suitably modified to comply with the functional requirements identified in the first objective.
- The integration of the RWC algorithm and HMI on RPAS high-fidelity simulators at CIRA and Deutsches Zentrum für Luft- und Raumfahrt (DLR) was started using preliminary prototypes. For fully completing the test facilities preparation for the RTS test campaign, the next activities will involve implementing the real-time test scenarios in each of CIRA's and the DLR's facilities.
- The test plan was defined in deliverable D4.1. This test plan takes into account aspects of requirements to be defined for fast-time simulation (FTS) and operational aspects for RTS that will be evaluated, as emerged from discussions with the SESAR JU, the Advisory Board and the stakeholder workshop. The FTSs are ongoing with the main aim being to define all aspects not quantified in the requirements included in deliverable D2.2. The RTSs will be performed separately at CIRA and the DLR using different simulated scenarios.
- Surveillance system performance requirements were defined in deliverable D2.1 and will be confirmed by the ongoing FTSs. Data link performances will be evaluated both in the FTSs (concerning the compatibility with the RWC function) and in the RTSs (concerning the workload induced on the remote pilots and controllers).
- The main performance criteria for the system performance evaluation were identified. Procedures mainly affected by the UAS insertion in airspace classes D–G were set out in the definition of the applicable use cases, and these are driving the definition of the test scenarios.

The activities related to the assessment of the RWC system requirements and its operational application will mainly be concentrated in the second part of the project.

The project also progressed in its communication activities. Several coordination meetings with other European projects were held. A stakeholder workshop was held, along with three meetings with the Advisory Board, also involving representatives from pilot, controller and industrial organisations. Interactions with representatives of standardisation working groups are ongoing, as some project partners have joined these groups.

USEPE

The U-space separation in Europe (USEPE) project will propose, develop and evaluate a ConOps and a set of enabling technologies aimed at ensuring the safe separation of drones (from each other and from manned aviation) in the U-space environment, with particular focus on densely populated areas.

In order to achieve this goal, four specific objectives have been identified. These are to:

1. identify the predetermined separator (the drones themselves or the U-space systems) throughout the strategic and tactical planning phases;
2. define and simulate a set of concepts to provide safe separation of different kinds of drones in each planning phase;
3. assess the impact of the proposed concepts on different KPAs, in particular on safety, capacity and efficiency, in order to derive conclusions and recommendations on the most adequate approach for each operational environment;
4. disseminate the project results to all stakeholders in order to collect their feedback regarding the appropriateness of the transition to the subsequent stages of the R&I cycle.

The main technical achievement during the reporting period was the submission of deliverable D3.1, the ConOps outline, which was approved by the SESAR JU. The document outlines the new separation method that has been proposed for separation in urban environments and the requirements that the separation method has to comply with.

During the reporting period, the activities related to the development of the design concepts were launched. The main work performed was related to task 4.1, the implementation of the design concepts, which included:

- a literature review of the available simulation environments for the analysis of drone traffic management in urban areas;
- the selection of a simulation environment in which the design concepts would be implemented;
- an analysis of the suitability of different cities to be used for the simulations, based on the availability of 3D geometries;
- the initial work on the implementation of drones' path planning in BlueSky.

These activities will be part of deliverable D4.1, the report on the design concepts implementation, at a later stage in the project (the second reporting period).

In addition, the deliverable D5.1, the validation plan, was submitted in October 2021 and approved by the SESAR JU.

Finally, USEPE shared its stepwise systems engineering approach to solving the drone separation problem in urban areas at the presentation of the final master's thesis on systems engineering (25 June 2021) of one member of the consortium at the Universidad Europea in Madrid.

X-TEAM

The X-TEAM project, focusing on extended ATM for door-to-door travel, was kicked off by the SESAR JU in June 2020. It aims to define, develop and initially validate a ConOps for the seamless integration of ATM and air transport into an overall intermodal network serving urban and extended urban mobility, including other available transportation means (surface and water), to enable door-to-door connectivity in up to four hours between any two locations in Europe. The project will take into account the transportation and passenger service scenarios envisaged for the next decades, according to baseline (2025), intermediate (2035) and final (2050) time horizons.

In order to achieve this goal, the following objectives have been identified:

- to define, develop and initially validate a ConOps for the the seamless integration of ATM and air transport into an overall intermodal network, including other available transportation means (surface and water), to enable door-to-door connectivity in up to 4 hours between any two locations in Europe, in compliance with the target assigned by the ACARE SRIA *Flightpath 2050* goals;
- to consider a ConOps for ATM integration in an intermodal transport network serving urban and extended urban (up to regional) mobility, taking into account the transportation and passenger service scenarios envisaged for the next decades, according to baseline (2025), intermediate (2035) and final (2050) time horizons;
- to undertake a preliminary evaluation of the ConOps against already existing and specifically defined applicable KPAs and KPIs, implementing both qualitative and, where possible, quantitative performance assessments;
- to integrate ATM and air transport into an overall intermodal transport system, to be considered not only with respect to currently available transportation alternatives on the surface and water, but also with respect to emerging new mobility forms that are envisaged for the next decades;
- to apply a simulation-based approach for validating the concept proposed in the project, thanks to a simulation platform that considers the most relevant elements of transport in the future, such as intermodal interfaces, the high-level network model and the passenger-centric paradigm, allowing the proposed ConOps to be validated with respect to proper KPIs.

During 2021, the following work was carried out to fulfil these objectives.

- The definition of urban and suburban mobility reference scenarios for multimodal transport for the baseline (2025), intermediate (2035) and final (2050) time horizons based on dominating trends in urban and suburban mobility; the identification and evaluation over the three time horizons considered of the most promising enabling technologies for multimodal transport, addressing both surface (road, rail and water transport modes) and aerial (small aircraft transportation system, short take-off and landing, vertical take-off and landing (VTOL) and precision approach tracking system) technologies; the definition of the multimodal transport use cases over the three time horizons considered, according to two specific types of passengers (business and personal) and three variants (no disruption, disruption with information in advance and disruption during travel); and the identification of the main barriers for the implementation of the scenarios and use cases, in both the aviation and the surface transport fields;
- the development of the outline of the ConOps for ATM integration in intermodal transport systems with references to mobility infrastructures and mobility services for passengers;

- the development of the validation plan, defining the validation methodology and planning the activities for validating the operational scenarios defined by the project;
- the definition of the benchmark model and KPIs to be used for simulated validation of the proposed ConOps and the initial implementation of the first ConOps elements in the benchmark model with related testing against the set of selected KPIs.

With respect to CDE activities, in addition to finalising the CDE plan and launching its project website, the project was presented at several following workshops and conferences. These included the SESAR Innovation Days in 2021, the Scandinavian Simulation Society's EUROSIM conference in 2021 (at which the paper 'Extended ATM for seamless travel (X-TEAM D2D)' was presented) and the passenger-centred mobility workshop organised by EUROCONTROL, ACARE, the Italian Institute for Sustainable Society and Innovation (ISSNOVA), Association for the Scientific Development of ATM in Europe (ASDA) and the H2020 project CAMERA.

Regular meetings were also organised with the Advisory Board, which includes representatives from the Amsterdam University of Applied Sciences, the University of Mexico, the University of Bremen, the University de la Plata (Argentina) and the Maritime University of Szczecin (Poland). Meetings with the Passengers Advisory Group were also organised, which includes representatives from the Promotion of Operational Links with Integrated Services (POLIS) network and the European Passenger's Federation (EPF).

1.4.2.3 Other exploratory research activities

1.4.2.3.1 SESAR Innovation Days

The SESAR JU's flagship conference, SESAR Innovation Days, is the main vehicle through which the SESAR JU shares its progress and disseminates the results of its ER programme. Unlike other scientific events in ATM research, the SESAR Innovation Days focus explicitly on long-term and innovative research.

More specifically, the objectives of the event are to:

- bring together the members of Europe's academic and scientific ATM research community and provide them with a platform to showcase their achievements and disseminate their results;
- in particular, disseminate the results of SESAR 2020 ER;
- report on the new thinking and ideas that have come out of SESAR's ER projects and how they can feed into ATM IR;
- provide a backdrop to the SESAR Young Scientist Award.

The 11th SESAR Innovation Days took place as a virtual event between 7 and 9 December 2021 featuring a combination of virtual networking events, technical sessions, comfort breaks, plenary talks, virtual exhibitions and one global panel discussion on higher airspace operations. Over 750 participants (unique visits) attended the event and 77 full papers and 30 posters were submitted and triple reviewed by the Programme Committee.

The SESAR JU organised the event with the support of the SESAR KTN ENGAGE project, which took responsibility for the programmatic (i.e. scientific) content. The opening session included a presentation summarising ENGAGE's achievements, lessons and legacy during its 4 years of work and providing an update on EngageWiki, the one-stop European knowledge hub developed by the ENGAGE consortium.

As indicated by the number of scientific submissions, the number of attendees and the results of a feedback survey, the SESAR Innovation Days continued to be an established and recognised scientific event, with many researchers choosing it as a forum to disseminate the results of both SESAR and non-SESAR research projects.

1.4.2.3.2 Young Scientist Award

Along with the publication of the call for contributions to the SESAR Innovation Days, the most recent annual Young Scientist Award was publicly launched on 10 May 2021, with a deadline for the submission of applications of 5 September 2021.

For the 2021 award, the scope was widened from previous years to two categories, namely PhD scientists, with the chance to receive a prize of EUR 5 000, and undergraduate or master's students, with the chance to win a prize of EUR 1 500.

Applications were welcome from citizens or residents of an EU Member State or a country associated with the H2020 research and development framework programme. Up to three shortlisted candidates for each category were invited to join the SESAR Innovation Days in 2021, where the winner of each category was publicly announced in a dedicated ceremony.

Each application was first checked against the eligibility criteria described in the 2021 Young Scientist Award contest rules (published together with the call). Successful applications were sent to the evaluation panel for the award phase. The evaluation panel comprised three members of the Scientific Committee. At the end of October 2021, the panel submitted its evaluation report to the SESAR JU. The report recommended a shortlist of three applicants per category and ranked them as follows.

PhD scientists category

- First place: **Philippe Monmousseau**, Ecole Nationale de l'Aviation Civile (ENAC), for his work on performance-based assessments in ATM. The jury commended him for his scientific rigour and for expanding the conventional KPIs to include passenger-centric data and interfaces with other modes of transport.
- Second place: **Gabriel Jarry**, ENAC, for his thesis on algorithms for the ground-based detection and analysis of atypical trajectories in the approach phase of flight, which the jury said had potential as a basis for developing new situation awareness alerting systems or novel support decision tools for ATC.
- Third place: **Isabel Metz**, DLR, for her thesis on bird strike prevention, a relatively understudied topic in ATM. The jury commended the research for trying to solve an everyday problem, a solution for which would undoubtedly enhance the level of safety and predictability of air traffic in Europe.

Undergraduate or master's students category

- First place: **Chen Xia**, Technical University of Madrid (Universidad Politécnica de Madrid), who addressed conflict anticipation and resolutions to mitigate the risk of mid-air loss of separation. The jury commended Xia for the approach taken and the remarkable level of knowledge and accuracy shown in her thesis.
- Second place: **Raul Saez Garcia,** Technical University of Catalonia (UPC), who investigated arrival scheduling considering a TBO using closely spaced objects. The jury commended the novel approach and scientific excellence demonstrated in his work.
- Third place: **Jan Evler**, Institute of Logistics and Aviation, Technische Universität Dresden, for his work on airline schedule recovery. If proven practically viable, the concept could be used

> to make allocation markets in ATM more effective, provided that its uptake can be achieved by all the stakeholders, which is a step still to cover, the jury noted.

The SESAR JU Executive Director endorsed the recommendation of the independent jury panel.

The shortlisted scientists were presented with their awards during the 2021 SESAR Innovation Days virtual event by the SESAR JU Scientific Committee members Rita Somogyi (part of the jury panel) and Peter Hecker (chair of the jury).

Congratulating the winners, Richard Frizon, SESAR JU Executive Director *ad interim* said:

> *I want to congratulate all the applicants, shortlisted candidates and our overall winners, Philippe Monmousseau and Chen Xia. These are the ones to watch, the talent that will help us deliver on our promise of a Digital European Sky!*

Furthermore, the SESAR JU was delighted to see the career of former SESAR Young Scientist, Ramon Dalmau-Codina, PhD, go from strength to strength. He is now a data scientist for EUROCONTROL and was listed by Forbes as one of the 30 scientists under 30 to watch.

1.4.2.3.3 SESAR Digital Academy

The SESAR Digital Academy, launched in 2019, is a learning initiative supporting Europe's future aviation and ATM workforce. The mission is to nurture Europe's brightest minds and advance learning, scientific excellence and innovation in aviation and ATM. The SESAR Digital Academy seeks to bring together under one umbrella access to SESAR ER activities and outreach relating to education and training, and is supported by the SESAR JU's KTN project, Engage.

In 2021, the academy focused again on virtual activities because of the COVID-19 pandemic. Despite these challenges, several activities were carried out under the umbrella of the SESAR Digital Academy: five webinars (each lasting 90 minutes) were organised and attracted, on average, 500 participants, amounting to a global audience of around 3 000 unique participants throughout the course of the year. These webinars featured content from the SESAR programme and usually consisted of three or four technical presentations followed by a moderated session to address questions from the audience. All material, including webinar recordings, presentations and question and answer (Q&A) sessions, has been made available online, constituting an invaluable educational online resource library for the future.

The Engage Summer School, organised under the umbrella of the SESAR Digital Academy and the Engage KTN project, took place between 30 August and 2 September 2021 as a virtual event. The event provided an opportunity for Engage and EUROCONTROL PhD students to present and discuss their work. It also featured presentations from industry experts and tutorials, aligned with the needs/requests of Engage PhD students, as well as presentations on projects funded by the Engage catalyst fund. Lecturers included SESAR JU experts. The event achieved the objective of establishing a forum for the exchange of ideas between representatives of industry and academia, thereby both fulfilling an educational purpose and supporting the uptake of academic research by ATM industry. More information on this event can be found in Section I.4.1.1.

The Engage KTN compiled a list of undergraduate and postgraduate programmes at European universities related to ATM and air transport. This database currently contains more than 100 European university programmes, opportunities for PhD funding, jobs or internships, and teaching resources. This database is publicly available as part of EngageWiki, which enables institutions to log in and enter or update their own data. This database provides an unprecedented overview for students and organisations interested in ATM.

The SESAR Digital Academy also used its communication channels to promote the SESAR Young Scientist Award by increasing awareness among potential applicants and providing an opportunity for previous winners and shortlisted applicants to share their results.

1.4.3 Strategic area of operation 3: Delivery of industrial research and validation

The SESAR JU met all of its objectives related to IR in 2021, as set out in Section III of the SPD for 2021–2023. This includes the following achievements and results.

- Validation exercises were executed and release 10 was closed. Release 10 was completed and the SESAR JU circulated the close-out report among the Programme Committee, which agreed with the outcomes.
- Validation exercises of release 11 were executed. The Programme Committee approved the release 11 plan in December 2020 and the validation exercises took place in 2021 as per the plan. Release 11 will be closed by April 2022.
- Release 12 was prepared. The Programme Committee approved the release 12 plan in December 2021.
- As regards the call with reference H2020-SESAR-2019-1 (IR-VLD wave 2 call for proposals), the H2020 Reporting and payments (REPA) including the projects reviews were executed.
- As regards the call with reference H2020-SESAR-2020-2 (IR-VLD wave 3 call for proposals), IR wave 3 projects were launched into execution. Five projects were launched into execution, of which three were IR projects (summarised in the current section) and two were VLD projects (further described in Section I.4.4.1.4).

In 2021, with the aim of assessing the maturity of the SESAR Solutions developed in the IR projects, the SESAR JU and its members finalised release 10 and executed release 11. In addition, the SESAR JU started the planning phase of release 12, which is expected to be completed in April 2022.

The first IR call, IR-VLD wave 1, with reference H2020-SESAR-2015-2, resulted in 17 IR projects and three transversal steering activity projects, all of which have been closed and are not addressed in this document.

In 2019, the SESAR JU ran the IR-VLD wave 2 call process, which led to the signing of 15 grant agreements (12 in IR (of which two addressed transversal activities) and three in VLD) and the launch of the corresponding projects into execution for a total value of EUR 142.3 million.

Furthermore, in 2020, the SESAR JU ran the IR-VLD wave 3 call process, which led to the signing of five grant agreements (three in IR and two in VLD) and the launch of the corresponding projects into execution for a total value of EUR 29.9 million.

Considering the impact of COVID-19 on some projects – in particular the constraints on staff availability imposed by teleworking, the difficulties in developing prototypes and in accessing the validation platforms, and the critical situation at airports – there were some delays in the execution of the tasks, putting at risk the delivery of the SESAR solutions. In order to solve the risk, a replanning of the activities was required, leading to grant duration extensions for 12 wave 2 and four wave 3 projects, as allowed by H2020. These extensions will result in the closures of these 16 wave 2 and wave 3 projects by June 2022.

This section presents the status of the projects resulting from the wave 2 and wave 3 calls for proposals and their main achievements in 2021, followed by the results and achievements of release 10, the execution status of release 11 and the preparation status of release 12.

1.4.3.1 Status of industrial research and validation projects under the wave 2 call (H2020-SESAR-2019-1)

The wave 2 call for proposals with reference H2020-SESAR-2019-1 ([32]) was conducted in 2019. It resulted in the award of 12 grants, amounting to a total value of EUR 129 932 520, and the launch into execution of the corresponding projects. These projects were intended to deliver their results between 2020 and 2022.

Of these 12 projects, two (PJ19 W2 and PJ20 W2) addressed transversal activities and their contributions in 2020 are summarised in Section I.4.1.1.

The other projects are summarised in the following subsections.

High-performing airport operations

Project **PJ02 W2**, which focuses on airport airside and runway throughput, aims to improve the efficiency and resilience of arrival and departure operations at capacity-constrained airports and to improve access to secondary airports. The project plans to address the human, technical, procedural and performance aspects of the following proposed improvements.

- Advanced geometric GNSS-based procedures in the TMA: enhancing TMA efficiency using more GNSS and advanced curved performance-based navigation (PBN) for arrival and departure operations. This covers the development of new support tools for ATCOs and airspace design concepts to enable a greater use of continuous descent operations.
- The evolution of separation minima for increased runway throughput: refining separation minima as a function of the operational conditions. The most constraining minima (wake, runway occupancy, etc.) to be applied will be determined and ATCO support tools will be further developed for better separations delivery, including delegating separation to the flight crew.
- Improved access to secondary airports: enhancing the availability and accessibility of airports with limited infrastructure in low-visibility conditions. Alternative ground surveillance will increase runway safety and will include both ATC and aerodrome flight information service requirements as a more cost-efficient and flexible ATS provision. From an airborne perspective, enhanced flight vision systems (EFVSs), synthetic vision guidance systems, combined vision systems and localiser performance with vertical guidance (LPV-100) capability will improve the approach and landing.
- The digital evolution of integrated surface management: extending the A-SMGCS routing and guidance functions to improve tactical conflict management in the taxi phase. Optimised routing and planning will deliver more accurate taxi times, improve predictability, and minimise delays and controller workload. Automation, airport collaborative decision-making and data links will support conflict management.
- Safety support tools for avoiding runway excursions: detecting, preventing and providing alerts of risks of runway excursions by synchronising the air–ground exchange of information on the runway surface condition.

In 2021, the project continued to refine the concepts and technologies required to support the improvements listed above. This was supported by a number of validation activities in the different

([32]) The call conditions were set out in the SESAR JU annual work programme for 2019. The call documentation is available on the European Commission's Funding and Tenders Portal.

areas, either in the planning phase or, for some, in the execution phase. The refinement of the project activities into deployable, stand-alone candidate solutions continued, considering, in particular, the impact of the COVID-19 pandemic on some validation activities. It is expected that, by the end of wave 2, the following solutions will be delivered.

- In the advanced geometric GNSS-based procedures in the TMA WP:
    - PJ02 W2-04.1, advanced curved approach operations in the TMA with the use of barometric altitude, targeting maturity level V2 by mid-2023;
    - PJ02 W2-04.2, advanced curved departure operations in the TMA, targeting V2 by mid-2023;
    - PJ02 W2-04.3, advanced curved approach operations in the TMA with the use of geometric altitude, targeting V2 by the end of 2022.
- In the evolution of separation minima for increased runway throughput WP:
    - PJ02 W2-14.2, second runway aiming point (SRAP), targeting V3 by mid-2023;
    - PJ02 W2-14.3, increased second glide slope, targeting V3 by mid-2023;
    - PJ02 W2-14.5, increased glide slope (IGS) to a SRAP, targeting V3 by mid-2023;
    - PJ02 W2-14.6a, enhanced optimised runway delivery for arrivals with ML, targeting V2 by mid-2023;
    - PJ02 W2-14.6b, enhanced optimised runway delivery for arrivals with flight-specific information, targeting V2 by mid-2023;
    - PJ02 W2-14.7, dynamic pairwise separations for arrivals, targeting V2 by mid-2023;
    - PJ02 W2-14.8, enhanced optimised separation delivery for departures, targeting V2 by mid-2023;
    - PJ02 W2-14.9a, dynamic pairwise wake separations for departures based on wake risk, targeting V2 by mid-2023;
    - PJ02 W2-14.9b, dynamic pairwise wake separation for departures based on differentiated airborne position and climb profile, targeting V2 by mid-2023;
    - PJ02 W2-14.10, dynamic pairwise runway separations based on ground-computed arrival runway occupancy time, targeting V2 by mid-2023;
    - PJ02 W2-14.11, dynamic pairwise runway separations for arrivals based on airborne-predicted arrival runway occupancy time, targeting V2 by mid-2022;
    - PJ02 W2-14.13, the delegation of arrival separation to the flight crew, targeting V2 by mid-2023;
    - PJ02 W2-14.14, MET data and services for wake turbulence separation, targeting TRL4 by mid-2023.
- In the improved access to secondary airports WP:
    - PJ02 W2-17.1, improved capacity and safety of runway operations at secondary airports in low-visibility conditions, targeting V2 by mid-2023;
    - PJ02 W2-17.2, airborne navigation capability to achieve LPV-100 / the category (CAT) II approach, targeting TRL4 by mid-2023;
    - PJ02 W2-17.3, airport safety nets for controllers at secondary airports, targeting an ongoing maturity level of V3 by mid-2023;
    - PJ02 W2-17.4a, EFVS operations supported by the use of active sensor technology, targeting an ongoing level of V2 by mid-2023;
    - PJ02 W2-17.4b, enhanced resilience to low visibility conditions in approach and landing operations, targeting an ongoing level of V2 by mid-2023;

- PJ02 W2-17.4c, synthetic vision guidance system for approach operations on LPV or ground-based augmentation system (GBAS) landing system CAT I guidance, targeting an ongoing level of V2 by mid-2023;
- PJ02 W2-17.4d, EFVS 100 ft operations on large commercial aircraft (infrared-visual enhanced vision systems on head-up display not combined with synthetic vision systems), targeting V2 by mid-2023.

- In the digital evolution of integrated surface management WP:
  - PJ02 W2-21.1, extended airport safety nets for controllers at A-SMGCS airports, targeting V3 by mid-2023;
  - PJ02 W2-21.3, digital surface management for airport vehicles, targeting V3 by mid-2023;
  - PJ02 W2-21.4, full guidance assistance to mobiles using 'follow the greens' procedures based on airfield ground lighting (aprons/taxiways/runways), targeting V3 by mid-2023;
  - PJ02 W2-21.5, enhanced safety in low-visibility procedures through the use of dynamic virtual block control, targeting V3 by mid-2023;
  - PJ02 W2-21.6, surface route planning and management operations, targeting V3 by mid-2023.

- In the safety support tools for avoiding runway excursions WP:
  - PJ02 W2-25.1, enhanced runway condition awareness for runway excursion prevention, targeting V3 by mid-2023;
  - PJ02 W2-25.2, support tools for pilots for better prevention of runway excursions and monitoring of aircraft trajectory, targeting an ongoing level of V1 by mid-2023;
  - the project will also perform some additional work on the V3 mature solutions PJ02-01-04 and PJ02-01-06, aiming to support deployment by integrating new aircraft and their wake vortex characteristics and by proposing guidance safety case assessment for regulatory authorities.

Project **PJ04 W2** on total airport management will develop concepts, tools and procedures to increase the predictability and resilience of airport operations, improving the punctuality of flights in a safe and environmentally sustainable manner. The project aims to improve airport–network integration for large and medium-sized or regional airports, to improve airport airside–landside integration, to reduce the impact of MET aspects on airport operations and to further investigate how environmental factors can be monitored and managed in day-to-day airport operations.

The aims will be achieved by increasing coordination between airports and the network, validating the concept of regional connected airports. On the airport side, the project focuses on the airport hypervision concept and how airport operations could be better predicted with anticipated impact, managed in a proactive way and synchronised in various situations. This includes the development of performance and role-based dashboards, as well as what-if, prediction and impact assessment tools. In this aspect, data-driven airport operations management and digital technologies are required enablers, as connected, data-based, intelligent toolboxes supporting all airport stakeholders must be developed.

Achieving the full benefits and the expected performance improvements in the context of the overall ATM network will require close coordination with other projects, particularly those addressing network management, airport airside and runway throughput, and enhanced arrivals and departures. as well as overall integration within the programme.

In 2021, for each of the candidate solutions within the scope of PJ04 W2, the project team continued to development the concept and the operational and technical elements. The planning of the

validations continued, with several exercises delayed by the severe impact of the COVID-19 pandemic on the airports and other stakeholders participating in the project. The PJ04 W2 candidate solutions are as follows.

- In the network connected airports WP:
    - PJ04 W2-28.1, connected regional airports, targeting V3 by mid-2023;
    - PJ04 W2-28.2, collaborative management at regional airports, targeting an ongoing level of V2 by mid-2023 (the solution achieved V1 at the end of 2021);
    - PJ04 W2-28.3, connected large airports, targeting V3 by mid-2021.
- In the digital smart airports WP:
    - PJ04 W2-29.1, airside/landside performance management, targeting V3 by mid-2023;
    - PJ04 W2-29.2, MET performance management, targeting V3 by mid-2023;
    - PJ04 W2-29.3, environmental performance management, targeting V2 by mid-2023 (at the time of writing of this report, the project team was working on the repackaging of the activities related to environmental performance management into two distinct candidate solutions, one targeting large airports and the other targeting regional airports).

Project **PJ05 W2**, on digital technologies for towers, aims to contribute to the increased digitalisation of ATM from two different angles. First, it proposes the development of a remote aerodrome ATS in which services from various aerodromes are combined in a centralised control room independent of airport location. Second, it intends to validate innovative HMI modes and related technologies in different airport towers. The project's solutions will not only provide shorter travel times and better point-to-point connections, but also increase flight safety and controller productivity.

In 2021, PJ05 W2 continued the operational and technical developments for each of the candidate solutions in its scope. It also progressed in terms of the planning and, in some cases, the execution of the validation activities.

The candidate solutions under the project's scope are:

- PJ05 W2-35, multiple remote towers and remote tower centres, targeting V3 by the end of Q1 2023;
- PJ05 W2-97.1, virtual/augmented reality applications for towers, targeting TRL4 by the end of Q1 2023;
- PJ05 W2-97.2, automatic speech recognition at the tower controller working position supported by AI and ML, targeting TRL4 by the end of Q1 2023.

Advanced air traffic services

Project **PJ01 W2** on enhanced arrivals and departures will develop concepts, tools and procedures to increase the capacity of TMAs in a safe, cost-effective and environmentally sustainable manner. This will be achieved by taking advantage of the latest technological developments from both an airborne perspective and a ground-system perspective and through the secure sharing of data. The needs of all AUs, including rotorcraft, will be addressed.

The aim will be to improve capacity while exploiting the environmental benefits achieved from optimised descent operations and improved arrival sequencing. A focus will be to minimise delays and improve the resilience and predictability of capacity-constrained high-density / high-complexity TMAs.

This will be achieved by enhancing arrival and departure management through the dynamic use of precision navigation routes and optimised profiles. Traffic flows will be optimised by improving the integration of the management of departures with arrivals, including E-AMAN and ground holding from in-horizon departures, and by improving the capability to balance traffic demand and available capacity across the network and airports.

The use of procedures and technologies to improve the integration of rotorcraft operations within TMAs and to improve interoperability with general aviation, drones and RPAS will be addressed, which will also provide increased resilience in poor weather.

In this reporting period, the solutions progressed in line with the plan. There were some changes to planned delivery dates, but these were discussed and agreed with the project team and with the SESAR JU. There was some, limited, impact caused by COVID-19, but this was kept to a minimum.

The work on all four solutions is on track to be completed by the end of December 2022; no extension due to the impact of COVID-19 is necessary for PJ01 W2.

The project's progress in terms of the four solutions is described below.

- PJ01 W2-08a1, short-term DCB optimisation of TMA and E-TMA airspace with a TMA management tool, will develop concepts for digital synchronisation of arrivals and departures in high-density / high-complexity environments. The solution will investigate the management of TMA/E-TMA traffic, taking advantage of predicted demand information provided by local arrival and departure management systems to identify excess demand on a sector or route or additional capacity and to balance the sector/flow load.
    - Solution 08a1 work progressed and is on track to address all V2 gaps from wave 1 within the planned validation exercises.
    - The delays caused in reporting period 1 by the split of the solution have been recovered and solution 08a1 is on track to meet its objectives by the end of December 2022. An intermediate V3 gate for PJ01 W2-08a1 concluded that the technical gaps from the transition from wave 1 to wave 2 are well covered by the solution. A number of minor actions were provided towards the successful completion of V3. All deliverables and milestones are in line with latest plan on STELLAR, the SESAR development support services (SDSS) collaborative platform used by the SESAR JU and by all projects for planning, scheduling and monitoring project progress. Preparatory work for the validation exercise was begun.

- PJ01 W2-08a2, automatic controlled time of arrival for the management of arrival en route and on the ground, will investigate the concept of the automatic imposition of arrival management constraints direct to the aircraft en route and on the ground prior to start-up for 'in-horizon' departures. It aims to validate the implications for both the ground and the airborne sides regarding automation of controlled time of arrival (CTA) constraints. It will also provide enhancement for ATM using upstream delay sharing to the aircraft and via ATC systems on the ground.
    - Solution 08a2 delivered initial and intermediate documents for the SESAR JU, the majority of which were approved with comments or are under revision by the SESAR JU.
    - A V1 gate for PJ01 W2-08a2 was held in June 2021. The outcome of the meeting was that V1 has been achieved for the solution with some recommendations made by the SESAR JU. The solution aims to achieve its target maturity of V2 by the end of 2022.
    - The solution delayed the RTS validation exercise to May 2022. This was because of resource availability in 2021.

- PJ01 W2-08b, dynamic E-TMA for advanced optimised descent operations, is based on four validation threads that will investigate dynamic TMA/E-TMA for advanced optimised descent operations in high-density / high-complexity environments. Across the threads there is an aim to improve airspace performance and the environmental efficiency of climb and descent operations. The expectation is that the threads will be split to separate solutions at the end of the wave, except thread b5, which is expected to provide complementary work to thread b1 in the current wave. Some of the threads are part of PJ37 W3-03. One of the threads of work, thread b3, has been stopped due to resourcing issues for the lead contributor, EUROCONTROL.
    - The solution is progressing in line with the expectations for V2. The deliverables and milestones are in line with the latest agreed plan on STELLAR. Regular monthly progress meetings have been held throughout the reporting period. These have been joint meetings held with PJ37 W3-03 since the start of wave 3.
    - An interim version of solution 08b, the OSED/SPR-INTEROP, validation plan and technical specification (TS) / interface requirement (IRS) documents have been delivered and approved by the SESAR JU.
    - A V2 intermediate maturity gate was successfully completed in September 2021, with minor actions and recommendations
- PJ01 W2-06, advanced rotorcraft operations in the TMA, will investigate the benefits deriving from the implementation of enhanced technology that better supports new, advanced procedures for rotorcraft, beyond those already researched in SESAR 1. The solution will seek to improve the integration of IFR rotorcraft operations within TMAs, assuring a high level of operational interoperability, safety, synchronisation and resilience and improved pilot (rotorcraft) and ATCO performances in the TMA environment populated by different AUs (major airlines and rotorcraft).
    - Overall the progress of solution 06 has been good and is aligned with the solution schedule to deliver its target objectives. During the reference reporting period, several meetings and workshops were conducted to support the solution works and ensure the progress of the proposed work.
    - All of the deliverables whose release date fell within the reference reporting period were formally delivered and approved by the SESAR JU.
    - The solution took part in the V1 maturity gate meeting. The meeting concluded with V1 being achieved and the solution being transitioned to the V2 phase, as the scope and benefits of and a validation approach to V2 were correctly identified. The solution is targeting V2 maturity at the end of wave 2.

Project **PJ10 W2** focuses on separation management and controller tools and builds upon previous work in SESAR 2020 wave 1. The project will further develop the concept of flight-centric ATC, which means that all ATCOs are responsible for a certain number of aircraft throughout their entire flight segment within a given airspace. Another objective is to enable collaborative control operations, which will allow ATCOs to issue instructions to aircraft that involve out-of-sector manoeuvring, without the coordination required in conventional operations. This will be accompanied by an activity to identify and validate needs that might allow an ATCO to operate in any airspace classified as a particular type. That is, the ATCO will be validated on the method and tools rather than on a specific geographical airspace.

In addition, the project will investigate and develop the contingency and delegation of airspace operational use cases. It will identify the impacts on the services defined in the virtual centre concept and validate the concept within a realistic environment based on contingency needs or on organisation

needs (either static (on a fixed-time transfer schedule) or dynamic (when the traffic density is below/above a certain level)). In order to reduce the workload and mental strain on the controllers in the ATC centre, especially in high-density / high-complexity situations, the project will investigate new HMI interaction modes and technologies. This work will consider modern design and development approaches, as well as methodologies such as modularity, service-oriented architecture and adaptive automation. The project will, in particular, address automatic speech recognition, attention guidance and enhanced user profile management systems (UPMSs).

The project will address the following solutions, which are currently being executed:

- PJ10 W2-73, collaborative control;
- PJ10 W2-73, flight-centric air traffic control;
- PJ10 W2-73, increased flexibility in ATCO validation;
- PJ10 W2-93, the delegation of ATM services provision among air traffic system units (ATSUs);
- PJ10 W2-96, automatic speech recognition;
- PJ10 W2-96, attention guidance;
- PJ10 W2-96, UPMS.

The SESAR JU kicked off PJ10 W2 in January 2020 and helped to structure the work required so that the project would deliver the EU policy objectives reflected in the ATM master plan, including the updated level 2 master plan, ensuring that they reflect the agreed scope of the project and link to the architecture vision of the airspace architecture study. In particular, the SESAR JU provided support to kick off the EUROCAE working group for the standardisation of the virtual centre, which is a key step in preparing the deployment of the virtual centre technology and the service-oriented architecture made possible by the modular ATM data service providers concept.

The SESAR JU has also supported the project in the successful scoping of the delegation of ATS activities that will be conducted, which include the game-changing use cases of night delegation (enabling the consolidation of ATC services during the night) and contingency delegation (supporting the resilience of the ATM network). In the area of automation (collaborative control, flight-centric ATC, automatic speech recognition and attention guidance), the SESAR JU provided support to the projects whose plans had to be changed owing to COVID-19 in order to prioritise the activities and ensure a coherent delivery in accordance with the priorities of the ATM Master Plan. Progress was made in all of the solutions during the year in the preparation of the validation activities to be conducted in 2022.

PJ10 W2-93, the delegation ATM services provision among ATSUs, reached the V2 maturity level during this reporting period.

Project **PJ13 W2** on IFR RPASs covers the integration of IFR RPASs into controlled airspace mainly used by airlines (classes A–C) by developing a framework for the insertion of RPASs into the non-segregated airspace, allowing their routine access and operations. It also develops a DAA system for IFR RPAS operations that will allow the remote pilot to contribute to safety by preventing collisions in the event of failure of normal separation provisions.

The project, subject to the signing of the 2021 grant amendment, plans to deliver solution 115 by the end of 2022 and solutions 111 and 117 by the end of March 2023.

The progress of the project and its three solutions is summarised below.

- PJ13 W2-111, collision avoidance for IFRs for RPAS. DAA systems for IFR RPAS have two functions: RWC and collision avoidance. For RPASs to be allowed into the airspace, the DAA

performance should be at least as good as the traffic collision avoidance system (TCAS II) and 'see and avoid' systems. Collision avoidance for RPASs (an aircraft collision avoidance system for unmanned crafts) is a DAA system that will be assessed.

  - During the reporting period, the design documents for solution 111 were completed (the intermediate OSED/SPR-INTEROP document, the CBA, the validation plan and the TS/IRS). The documents were throughly reviewed and commented on, and were finally approved by the SESAR JU. Solution 111 reached the intermediate maturity gate, with the SESAR JU providing a number of recommendations. There have been many coordination meetings with the SESAR JU to address the recommendations and gain clarity on the concept.
  - As part of this solution initial encounter models, an encounter generator and revised encounter models were developed.
  - Like the project overall, the solution has made good progress towards achieving the expected maturity level (V3) by the end of wave 2.

- PJ13 W2-115, IFR RPAS accommodation in airspace classes A–C. This solution aims to accommodate IFR RPASs, in the short to medium term, during their transit phase through non-segregated controlled airspace classes A–C by establishing harmonised procedures across European airspace of low/medium density and complexity. The SESAR RPAS accommodation solution targets reduced planning and approval time and routine access of small numbers of IFR RPASs.

  - Solution 115 delivered its OSED/SPR-INTEROP document and validation plan as planned, and both were approved by the SESAR JU.
  - The work on this solution progressed well during the year; it reached the V2 maturity level, with a number of recommendations provided by the SESAR JU. The SESAR JU provided continuing support to the solution in terms of broadening its scope in order to provide, as far as possible, a solution that was relevant at European level, even though it was based on the experience of mitigations that have been successful at local level. As part of the solution, a stakeholder workshop was organised to get wider European buy-in.

- PJ13 W2-117, IFR RPAS integration into airspace classes A–C. This solution aims to enable IFR RPAS to operate alongside manned aircraft in the controlled airspace classes A–C completely transparently, with no mitigations because they are unmanned. The long-term operational concept will be developed in order to allow RPAS to file a flight plan, obey ATC instructions, follow clearances and deal with emergencies in a manner that is safe and fully understandable to ATCOs, with no additional adverse effect on the ability of the ATM system to handle IFR RPASs in this cooperative environment.

  - During the reporting period, the SESAR JU supported this solution by helping to refine its scope and concept in order to ensure consistency with the rest of the SESAR programme and the objectives of the ATM master plan.
  - The solution reached the intermediate maturity gate and made progress towards the recommendation made by the SESAR JU. The OSED/SPR-INTEROP document and validation plan were also both delivered and approved by the SESAR JU.
  - The solution is progressing through the preparation of the validation exercise, which aims to reach the V2 maturity level by the end of wave 2.

Project **PJ18 W2**, 4D skyways, builds on previous work of SESAR 2020 wave 1 and continues the research on trajectory management to enable the deployment of the SESAR TBOs. This project deliver mature trajectory management operational improvements to accelerate deployment and to achieve the associated benefits. In the longer term, it will also work on the definition of a consolidated

trajectory management solution to drive the coherence and efficiency of research on trajectory management and on architecture alternatives to address European ATM fragmentation.

PJ18 W2 started in December 2019 and, subject to the signing of the 2021 grant amendment, solutions 57 and 88 are intended to be delivered and closed by the end of 2022, whereas solutions 53 and 56 are intended to be delivered and closed by the end of June 2023.

The project and its five solutions progressed as described below.

- PJ18 W2-53a, increased automation in planning and tactical separation management. This solution develops and validates enhanced assistance to the en route and TMA (planner or tactical) controllers in their conflict detection and resolution tasks. It provides enhanced resolution support information based on predicted conflict detection and associated monitoring features.
    - During the reporting period, the solution delivered all of its design phase deliverables (the initial OSED/SPR-INTEROP document, the initial TS/IRS and the validation plan) to the SESAR JU, and these were either approved by the SESAR JU or resubmitted.
    - The development and validation phase activities – including prototype and platform development – are ramping up. V2 maturity will be reached at the end of wave 2.
- PJ18 W2-53b, improved performance of conflict detection and resolution tools enabled by reduced trajectory prediction. The solution will provide the (planner or tactical) controller with conflict detection and resolution tools that use more accurate parameter settings and are based on an enhanced ground-predicted trajectory through the use of improved and/or additional relevant data (e.g. aircraft trajectory data downlinked via automatic dependent surveillance contracts (ADS-Cs) or more recent weather information). Improved and/or additional relevant trajectory data may be made available via air–ground data link exchanges (e.g. using real recorded downlinked ADS-C information).
    - During the reporting period, it was concluded that solution 53b (ongoing V2 maturity) is on track to close the V2 gaps, albeit with a number of elements to be followed up with the objective of allowing solution 53b to achieve target maturity V3 by the end of wave 2.
    - Solution 53b's design phase was completed. All of the deliverables of the solution were submitted to the SESAR JU in line with the PJ18 W2 project management plan (the initial V3 OSED/SPR-INTEROP document, the initial V3 TS/IRS and the V3 validation plan). The solution has started the development and validation phase.
- PJ18 W2-56, air/ground trajectory synchronisation via lateral and vertical complex controller–pilot data link communications clearances to support TBOs.
    - The solution will involve researching enhanced operational procedures that make more efficient use of controller–pilot data link communications with lateral and vertical data link clearances. The proposed work will improve the alignment of the airborne trajectory with the trajectory that the ground actors plan to execute by sending complex clearances more and more in advance. The airborne trajectory will become more useful on the ground, as it will integrate the impact of future ground actor's instructions, allowing more efficient decision-making. With the proper automation, this will decrease both ATCO and flight crew workload, also leading to better management of ATC and flight crew resources.
    - During the reporting period, solution 56 delivered all of its design phase deliverables and – further to resubmissions – the initial OSED/SPR-INTEROP document, the initial TS/IRS and the validation plan were all approved by the SESAR JU. The development and validation phase activities, including prototype and platform development, are ramping up.

- PJ18 W2-57, study of benefits of increased automation in ATM.
    - Solution 57 aims to address the definition and validation of new greater levels of automation of air–ground and ground–ground trajectory exchanges (e.g. ground tools and airborne tools using big data analytics and ML, machine reasoning and multicriteria ranking of resolutions, and what-if air–ground trajectories).
    - The leadership of solution 57 has been transferred from DFS to NATS and, after a ramping-up period, the initial V1 OSED was recently submitted. The SESAR JU has requested that the solution address a number of assessment comments, including a remark on the suitability of the ground-side framework as an outcome for a SESAR Solution. The solution 57 validation plan for V1 was submitted to the SESAR JU on 17 December.
    - A solution 57 'checkpoint' took place with the SESAR JU on 17 January, which provided an opportunity to make progress on the SESAR JU comments from the OSED assessment and on the status of the change requests (CRs) for the operational improvements.
    - The trajectory management document was removed from solution 57 and relaunched at project level, with a lead technical writer from EUROCONTROL, a larger group of project partners and a coordination with PJ07, PJ19, the NM, the EUROCONTROL internal TBO forum and the SESAR JU. The work is ramping up, with a formal delivery to the SESAR JU planned during the next reporting period.
- PJ18 W2-88, trajectory prediction service. In support of the transition to TBOs, PJ18 W2-88 is researching and developing a common service to provide a single point of reference for a specific trajectory during all phases of flight. The service is based on unifying a number SESAR solution architectures and optimising the trajectory aspects for cost-effective delivery into operation. The service covers the period from creation in long-term preflight planning through to the flight execution phase.
    - During the reporting period, solution 88 reached the intermediate maturity gate, at which point a number of recommendations were made concerning the achievement of TRL2 and engagement with the stakeholders affected.

Optimised ATM network services

Project **PJ07 W2**, which focuses on optimised airspace users' operations, aims to enhance the integration of the AU trajectory and the mission trajectory into network management processes to increase the involvement of civil and military AUs in ATM collaborative processes.

- PJ07 W2-38, enhanced integration of airspace users' trajectory definition and network management processes, kicked off in 2020.
    - The objective of this solution is to reduce the impact of ATM planning on AUs' costs of operations, by enabling them to better cope with ATM constraints and to exploit network opportunities. Among other benefits, better collaborative decision-making and planning between providers and users ensures better adherence to the agreed trajectory during execution and, hence, better predictability of traffic demand.
    - The solution is intended to improve AUs' flight planning and ATM network management by improving the participation of the flight operations centre (FOC) in the ATM network collaborative processes in the context of flight and flow information for a collaborative environment and its potential evolutions.

- The concept of solution 38 addresses two topics regarding trajectory planning in the tactical ATFCM phase (day of operations):
  - the use of enhanced what-if functions, enriched DCB information such as hotspots and congestion indicators to allow AUs to assess the network DCB impact on a flight plan or preliminary flight plan;
  - the use of AU preferences in DCB processes to indicate AU preferred measures for a flight in case of DCB constraints, that is, the implementation proactive flight delay criticality indicators.

  For these two topics, initial sets of requirements have been set out in the initial OSED and in benefits mechanism diagrams. Technical requirements have been developed for the enriched DCB topic. The validation roadmap has been defined. Validation expectation and needs have been captured from various stakeholders (ANSPs, the NM and AUs) and validation objectives have been defined for both topics. The first exercise has been conducted, namely to have automatic simulation on enriched DCB performed successfully.
- As part of solution 38, work was also initiated on the initial description of the FOC management of the reference business trajectory (RBT) (trajectory planning in the execution phase). In addition, the RBT revision task was launched in coordination with PJ18 and an initial paper was developed and discussed with partners.

- PJ07 W2-39, collaborative framework managing delay constraints on arrivals, kicked off in 2020.
  - This solution focuses on developing a collaborative framework that will enable the integration and necessary coordination of 4D constraints (limited to arrivals management) from various stakeholders (airports, ANSPs, AUs and the NM). This will ensure the continued stability and performance of the network and will enable AUs to prioritise their most important flights, thereby reducing the impact of ATM planning constraints on the costs of their operations.
  - The main objective of this solution is to define and validate a framework to enable coordination of and collaboration between different ATM processes (including UDPP), dealing with delay constraints on arrivals (considered the most important contributor to capacity performance issues).
  - As part of solution 39, the task of defining how to ensure continued stability and performance of the network was initiated, which will give AUs the opportunity to prioritise their flights, thereby reducing the impact of the delays generated by ATFM planning constraints, and to limit the additional costs for their operations. In this framework, the AUs may contribute to a DCB solution so that their operational performance interests are best served.
  - Further development of the definition of the operational and technical requirements have been conducted as part of the solution. The validation expectation and needs that were captured from various stakeholders (ANSPs, the NM and AUs) were initially transferred to the validation objectives. In addition, two exercises have already been executed: the first focused on UDPP performance assessment and the second was the Zurich trial. The outcome of the exercises will be set out in the validation report in 2022.

- PJ07 W2-40, mission trajectories management with integrated dynamic mobile areas (type 1 and type 2), kicked off in 2020.
  - This solution contributes to the target ATM concept by demonstrating a comprehensive approach to the development, by military operational stakeholders and the NM, of military

ATM demand to be integrated into the ATM network operations. It details the concept of mission trajectories facilitating the integration of the airspace reservation/ restriction (ARES) based on a new dynamic mobile areas concept (dynamic mobile area types 1 and 2) into the TBO environment through seamless airspace management, ATFCM and ATS processes at local and subregional levels.

- The dynamic mobile areas concept should be understood as a complementary solution to the already developed and validated concept of variable profile areas in the context of mission trajectory.

In this period, initial sets of operational and technical requirements were produced. In addition, the initial validation objectives were defined and drafted.

PJ09 W2, which focuses on the digital network management service, is intended to enable both civil and military AUs to make better use of the available airspace capacity by increasing the granularity and flexibility of airspace configuration and management within and across ANSPs' areas of responsibilities. Increasing the digital information available in the network operations plan will ensure that all interested parties (e.g. for traffic forecasts and traffic complexity representations) have up-to-date, real-time ATM situational awareness.

- PJ09 W2-44, dynamic airspace configurations, kicked off in 2020.
  - This solution aims to improve both civil and military AUs' use of airspace capacity by increasing the granularity and the flexibility of airspace configuration within and across ANSPs' areas of responsibility.
  - It addresses the integration of concepts and procedures to allow flexible sectorisation to be dynamically modified based on demand. This includes potential impact assessment for ATCO licences, international boundaries and, potentially, interoperability and air–ground multi-data link communication capabilities.

  The core focus of the PJ09 W2-44 solution is the use of the dynamic airspace configurations concept in the DCB process including the concept of integrated network management ATC planning (INAP), in an integrated way, and not as two different steps. A particular emphasis will be put on the INAP time frame where the two overlap. An INAP time frame could be established of between a few hours and a few minutes before a spot occurs (e.g. from about 6 hours to about 15 minutes before), with the limits thresholds being adjusted according to local specificities.

To reach its goal, the following further development activities (at both operational and technical levels) were conducted as part of PJ09 W2 by the solution team:

- the further development of the dynamic airspace configurations concept, notably optimised configurations and seamless integration of dynamic airspace configurations at pre-tactical and tactical phases;
- adequate automatic support for spots detection, traffic analysis and measures monitoring;
- the development of new features to support analysis and resolution, namely what-if and what-else functions;
- the development of new indicators to fine-tune analysis and to ease monitoring in terms of the complexity and the uncertainty;
- the alignment of processes, roles and measures and the definition of the right level of coordination and shared situation awareness at local, subregional and regional network levels.

The first validation exercise focusing on the demand and capacity measures for tactical imbalance resolution based on complexity has been executed.

- The main objectives of PJ09 W2-45, which focuses on enhanced network traffic prediction and shared complexity representation, are to:
    - improve demand prediction in the pre-tactical and tactical phases;
    - smooth the transition from traffic forecast (D1) to traffic demand (D1/DO);
    - develop the use of uncertainty representation as a complement to the entry and occupancy counts;
    - develop the consolidation of the local hotspots (in the tactical phase), including their complexity, represented by new, common, sharable and operable complexity indicators;
    - improve the collaborative network operations plan.

  Solution 45 was successfully kicked off in January 2020 and good progress was made during 2020. Initial versions of the OSED, validation plan and TS were delivered and one exercise was executed based on AI technology for improving traffic predictability.

  Solution 45 was closed by the end of 2020 because of the impact of COVID-19 and, as a result of this early closure, some elements of the concept will be developed and validated directly with the NM, allowing possible early deployment into operations. The initial data pack will be produced by using the initial set of documents provided.

- The main objective of PJ09 W2-49, which focuses on collaborative network performance management, is to contribute to improving network performance to achieve mutual benefits within the context of collaborative decision-making.
    - Solution 49 involves developing three pillars to support this approach:
        - resilience transition management,
        - an AI-based digital network (detection and resolution),
        - a network performance dashboard.
    - Solution 49 was successfully kicked off in January 2020 and good progress was made during 2020. Initial versions of the OSED, validation plan and TS were delivered and the development of a prototype of a network performance dashboard was started, which was initially used as a demonstrator of the concept and proposed as tool for the NM.
    - Solution 49 was closed by the end of 2020 because of the impact of COVID-19 and, as a result of this early closure, some elements of the concept will be developed and validated directly with the NM, allowing possible early deployment into operations. The initial data pack will be produced by using the initial set of documents provided.

PJ14 W2, which focuses on integrated CNS solutions, has as its main goal the development of an integrated suite of CNS solutions to overcome the inefficiencies of fragmented services while improving the operational efficiency of the ATM system in the short, medium and long term. In the communications area, it covers multilink technologies to enable the digital transfer of flight-critical data and voice communications between aircraft and ground ATM services in a resilient, secure and timely manner. The navigation solution consists in the development of satellite navigation-based robust positioning for all phases of flight, taking advantage of signals from multiple constellations, including Galileo. In the surveillance domain, the project harmonises and integrates cooperative and

emerging non-cooperative sensors, advanced multisensor data fusion capabilities, and security-related functionality together with methods of and tools for surveillance performance monitoring.

- PJ14 W2-76, integrated CNS and spectrum, is a transversal solution that aims to increase CNS consistency across domains, in terms of robustness, spectrum use and interoperability, including the civil–military aspects, by providing a global view of future CNS services and defining the future integrated CNS architecture (and CNS spectrum strategy).
    - The solution builds on the work carried out in wave 1 under PJ14-01-01.
    - The solution will federate all the project's solutions to ensure a harmonised and integrated approach to the coordination of and contribution to transversal and operational project activities. Updated versions of the CNS service assessment for V1 and the CNS performance-based approach for V3, along with a CNS evolution roadmap and strategy for V4, were completed in 2021.
- PJ14 W2-60, future communication infrastructure (FCI) terrestrial data link (L-band digital aeronautical communications system (LDACS)), builds on the work performed by SESAR solution PJ14-02-01 and covers the technical enabler entitled 'New air–ground data link using aeronautical telecomunication network (ATN) / internet protocol suites (IPS) over L-band (CTE-CO_2e)'.
    - The objective of solution 60 is to integrate and verify the LDACS data link with ATN services in a relevant end-to-end environment.
    - This solution will focus on the ground component of the air–ground data link and aims to take it to TRL6. The air component will be addressed under a complementary call under PJ33 W3 (FALCO).
- PJ14 W2-61, hyperconnected ATM, explores the concept of enlargement of the FCI (as defined by PJ14 W2-77) through the integration of open network services and commercial public radio links or technologies. The resulting hybrid open/protected 'hyperconnected' communication infrastructure is intended to be an enabler of future ATM and U-space operations, supporting safety and non-safety air–ground and air–air data. The hyperconnected ATM concept definition and functional requirements document for V1 were completed in 2021.
- PJ14 W2-77, FCI services, addresses FCI network technologies and seeks to validate and standardise the FCI elements that integrate all components of the end-to-end communication chain for safety-critical applications. These include the future data link systems (LDACS, satellite communications (SATCOM) and aeronautical mobile airport communication systems) and ground infrastructure elements.
    - This solution also addresses transversal topics such as security, safety, deployment and civil–military interoperability with ground–ground communications networks. Wave 2 is continuing and is completing the work performed by PJ14-02-04 in wave 1.
    - The objective is to achieve TRL6 for the FCI elements needed to support ATN baseline 1 services, ATN baseline 2 services, future ATN baseline 3 services (the solution will provide for such services in the future), airline operational control services and safety SWIM services, as well as interoperability with aeronautical telecommunication network open system interconnection ATN/OSI systems and infrastructure.
    - A contribution has been made to the solution for an overall ConOp for FCI services for TRL6 by the initial TS/IRS for FCI services. All other tasks, including the development of deployment and transition strategies and the building of prototypes, continue to progress.

- PJ14 W2-107, future SATCOM data link, addresses the development of future satellite data link technologies, also referred to as long-term or class A SATCOM, for both continental and remote/oceanic regions to support the future concepts beyond 2020.
    - The solution represents one of technologies that in solution 77 are called 'ICAO technologies' (FCI services). It is an essential part of a seamless, resilient and integrated FCI to allow the real-time sharing of 4D trajectories and timely access to ATM data and information services.
    - In terms of performance benefits, the solution will increase data link availability and capacity and will improve safety and security (resilience). The solution represents a technical enabler that is required for achieving the performance and safety objectives of the 4D trajectory management operational concept.
    - This solution is making progress on the work performed under PJ14-02-02 in wave 1 on long-term class A SATCOM. The initial TS/IRS on future SATCOM was completed in 2021 and coordination continues with the European Space Agency (ESA) Iris project as regards the availability of airborne prototypes. In particular, the activities in wave 2 will include the completion of technical specifications; the completion of the development and specification of a performance monitoring and control concept for long-term SATCOM in ATN/IPS; contributing to the functional FCI architecture developed by and under the responsibility of solution 77 (FCI services); the development of SATCOM voice as a full high-frequency alternative in oceanic and remote continental airspace; in coordination with the ESA Iris project, ensuring, in the long term, harmonisation at global level of the proposed solution; technical validation at TRL6 ongoing and taking the next steps towards reaching TRL6 of satellite air–ground data link for long-term SATCOM integrated in the FCI; and supporting the production of the required standards at global level.
- PJ14 W2-100, SWIM technical infrastructure purple profile for air–ground safety-critical information-sharing, addresses the distribution (uplink and downlink) of safety-critical information through air–ground SWIM infrastructure and ATN/IPS networking, rather than legacy point-to-point contracted services.
    - The aim is to analyse, design, specify and validate the purple profile for safety-critical information-sharing. The solution concerns only the SWIM infrastructure layer: design, specification and prototyping of the SWIM services and network layers demand other solutions.
    - The solution will, when relevant, build on the results from the SESAR 2020 wave 1 projects PJ17-01 and PJ17-07 and deployed SESAR 1 solutions specifically related to SWIM. SESAR 2020 wave 1 outcomes will be further constrained, taking into account the domain (safety-critical) and the analysis of the OSED and the SPR concerning candidate safety-critical air–ground SWIM services.
    - The solution is a technical enabler (for the SWIM infrastructure layer only) allowing an aircraft to be integrated into the SWIM network and thus giving it access to air–ground safety-critical SWIM services. SWIM-enabled aircraft, flight crews and ground-based systems will all benefit from the SWIM concept and principles. The solution completed TRL2 within 2021 and is now targeting maturity level V2/TRL4.
- PJ14 W2-101, SWIM technical infrastructure green profile for ground–ground civil–military information-sharing, aims to enable ground–ground civil–military SWIM-based coordination at the SWIM technical infrastructure level by developing SWIM profiles with adequate quality of service, including the (cyber)security needed by military stakeholders and agreed by civil stakeholders.

  - This solution aims to increase cost-efficiency and improve civil–military cooperation and coordination.
  - The solution provides specifications for security and performance in addition to those in the SWIM yellow profile standard in order to maximise civil–military interoperability at the minimum cost.
  - The solution builds on the results of the SESAR 2020 wave 1 project PJ17-03. The objective is to reach V3/TRL6 maturity, such that the complementary green profile technical requirements can be integrated with the yellow profile standard for standardisation. The TRL6 initial TS/IRS SWIM technical infrastructure green profile was completed in 2021.

- PJ14 W2-79, a dual-frequency / multiconstellation GBAS, aims to advance as a technical enabler and to take advantage of the operational benefits that GBAS can provide. In addition, the aim of this solution is also to make advancements in the standardisation activities with the existing working groups on dual-frequency multiconstellation systems at the level of the Radio Technical Commission for Aeronautics (RTCA) and the ICAO/Navigation systems panel (NSP).. These activities were included in solution 79a on GBAS approach service type (GAST)-D ionospherics. The airborne architecture, including advanced received autonomous integrity monitoring and the satellite-based augmentation system (SBAS), will not be addressed because of the very low contribution from the airborne side. Support for dual-frequency multiconstellation standardisation activities will remain. With respect to solution 79b, which includes GAST-F, the project will advance in the definition at both system level and subsystem level (for the ground segment) towards the TRL4 maturity level, but this is currently constrained by the airborne segment maturity. By way of recovery, the objective will be to promote the definition of the standards at RTCA and ICAO levels. As part of the solution, the TRL4 initial TS/IRS for GAST-F was completed within 2021.
- PJ14 W2-81, alternative position, navigation and timing (A-PNT), has as its objective the development of an A-PNT system as a technical enabler to support PBN / required navigation performance (RNP) operations in the event of GNSS degradation or outage. The solution addresses two different levels of maturity for the two main subsolutions, namely the mid-term solution and the long-term solution.
  - The mid-term solution, 81a, develops, consolidates and tests the multi-distance measuring equipment (DME) approach with autonomous integrity monitoring to V3/TRL6 maturity level. The TRL6 ongoing TS/IRS A-PNT multi-DME and received autonomous integrity monitoring algorithm was completed in 2021.
  - In the long-term solution, newer technologies and hybrid techniques will be investigated, including terrain-aided and vision-based navigation, targeting full TRL4. This will involve the investigation of enhanced DME (solution 81b), LDACS (solution 81c) and vision- / terrain-based navigation (solution 81d). The operational concepts developed in the long-term subsolution aim to reduce the congestion of L-band while minimising the changes required to on-board and ground hardware. For solution 81b, the TRL2 data pack for enhanced DME was approved, along with the TRL4 initial TS/IRS. For solution 81c, the TRL4 initial TS/IRS for enhanced DMEs was submitted. Finally, for solution 81d, the TRL4 initial TS/IRS and CBA were completed for terrain- / vision-based navigation in 2021.
- PJ14 W2-110, aircraft as an aeronautical information management / MET sensor and consumer, continues the development work of PJ01 in wave 1, although the objectives were refined in 2020.

- The target remains the development of new and the improvement of existing aeronautical information management / MET services to support the use of weather data by systems for flight management, efficiency and environmental sustainability.
- The solution is intended to improve the performance of services by providing better localisation of phenomena, a higher update frequency, and improved predictions and comprehensive observation coverage.
- The solution will improve awareness among the crew, the airline dispatcher and the ATCO of weather and climate-impacting conditions encountered by aircraft.
- The solution will support an awareness and monitoring of underperformance of GNSS services due to environmental events and will disseminate information about GNSS.
- By supporting the processing of aeronautical Information, the solution will enable more accurate predictions of operational flight constraints. Future enhancements will address: (1) improvement in weather information (a fusion of local observations from aircrafts and predictions from the ground) and (2) services applications to increase the efficiency of relevant operations. The TRL4 intermediate TS/IRS on aircraft as an aeronautical information management / MET sensor and consumer was completed in 2021.
- The target environment is en route, as well as airport/TMA. Air–ground and ground–ground communications are considered.

- PJ14 W2-84, new use and evolution of cooperative and non-cooperative surveillance, aims to address the separate evolution of non-cooperative surveillance systems (e.g. multistatic primary surveillance radar and video trackers) and cooperative surveillance systems (e.g. ADS-B, and airport and wide-area multilateration systems), as well as to establish new surveillance sensors to support emerging operational needs (e.g. multiple remote tower surveillance). A further objective is the harmonisation and development of surveillance performance monitoring tools to support a performance-based surveillance approach. This complex work package was divided into six solutions:
  - PJ14 W2-84a, new use and evolution of cooperative and non-cooperative surveillance – multisensor data fusion (TRL6), for which the TRL6 initial TS/IRS was completed in 2021;
  - PJ14 W2-84, new use and evolution of cooperative and non-cooperative surveillance – multiple remote surveillance modules (TRL6), for which the TRL6 initial TS/IRS was completed in 2021;
  - PJ14 W2-84c, new use and evolution of cooperative and non-cooperative surveillance – secured surveillance systems (single and composite systems) (TRL6), for which the TRL6 initial TS/IRS was completed in 2021;
  - PJ14 W2-84d, new use and evolution of cooperative and non-cooperative surveillance – future automatic dependent surveillance-B communications link (TRL6), for which the TRL6 initial TS/IRS was completed in 2021;
  - PJ14 W2-84e, new use and evolution of cooperative and non-cooperative surveillance – surveillance performance monitoring tool for cooperative sensors (TR-L6), for which the TRL6 initial TS/IRS and CBA were completed in 2021;
  - PJ14 W2-84f, new use and evolution of cooperative and non-cooperative surveillance – surveillance performance monitoring – end-to-end (TRL4), for which the TRL4 data pack including the final TS/IRS, etc., was completed in 2021 and work is ongoing towards TRL6.

1.4.3.2 Status of industrial research and validation projects under the wave 3 call (H2020-SESAR-2020-2)

The objective of the wave 3 call for proposals was to ensure that the widest possible range of the R&I topics identified in the SESAR 2020 programme as necessary to address ATM master plan phase C were covered through research, taking due account of the outcome of the airspace architecture study.

Following consultation with the Programme Committee, the final wave 3 call conditions were documented in the 2020–2022 SPD and were used to make the financing decision for authorising the launch of the call for proposals and for the use of the dedicated budget. The wave 3 call was published at the beginning of 2020 with a short deadline and required proposals to be submitted in Q2 2020. The SESAR JU then evaluated the proposals very quickly, allowing the grant agreement preparation phase to be launched in September. Grant agreements were signed in December 2020 and the execution of wave 3 projects started in January 2021. The SESAR Solutions were developed and the validation activities were prepared during 2021 with the objectives of executing the validation in 2022 and delivering the SESAR Solutions towards the end of 2022 and in early 2023. IR-VLD wave 3 is the final call covering IR, securing the commitment of SESAR JU members until the end of the SESAR 2020 programme operations.

Five projects, which were awarded in total EUR 29 925 861.82 (i.e. 99 % of the funds available under the call), have been launched into execution, three of which are IR projects (summarised below) and two are VLD projects (summarised in Section I.4.4.1.4).

Project **PJ32 W3**, virtual centre, complements SESAR Solution PJ10 W2-93 on the delegation of ATM services provision among ATSUs, in terms of it addressing airspace delegation, and SESAR solution PJ09 W2-44 on dynamic airspace configurations, as regards investigation of the cross-border use of the dynamic airspace configuration. PJ32 W3 aims to further validate airspace delegation in the virtual centre context (airspace delegation for two ATSUs – either from two different ANSPs or from the same ANSP – that can deliver service over the same volume of airspace, potentially including a cross-border rostering scheme). In addition, it aims to increase the maturity level of the virtual centre concept itself. The overall objective is to demonstrate the positive impact of the virtual centre concept on the network by:

- improving its ability to dynamically adapt to changes in capacity, for example in the event of contingency in an ATSU, traffic needs or an ATCO shortage;
- increasing cost-efficiency through the decoupling of ATM data provision from ATC service provision, thus enabling flexible, scalable and resilient ATM service provision.

The SESAR JU kicked off PJ32 W3-VC in January 2021.

Good progress was made in the project during 2021. An initial version of the validation plan was delivered and the development of a prototype for the PJ10 W2-P3 solution was started.

Coordination and collaboration activities with the PJ10 W2-P3 solution are being conducted and are leading to support and contributions from the PJ32 project to PJ10 W2-P3 deliverables (e.g. the OSED, TS and validation plan).

The objective of project **PJ33 W3**, FALCO, is to increase the efficiency of ATM in two different ways.

1. Building on the work done in PJ10 W2-73, ATC capacity will be increased by investigating and validating changes in techniques and procedures to enable the reorganisation of the endorsement of ATCOs working in the lower and upper area control services (explicitly excluding the approach control service). This will be achieved by introducing new endorsement rules that are based more on traffic complexity, sector classes, and controllers' skills, experience and training in a specific class of working environment and supporting system.
2. The efficiency of air–ground communication will be increased by investigating the technical enabler to broadly introduce voice capability supported by LDACS with the ultimate goal of replacing analogue voice communication. Furthermore, the future air–ground terrestrial data link (LDACS) will increase connectivity between the air and ground, something that is essential for future concepts, and will also support the resilience of aircraft navigation.

The SESAR JU kicked off PJ33 W3, FALCO, in January 2021 and WP3 is linked to enabling infrastructure in PJ14 W2 ICNSS, namely solution 60 on LDACS.

Both project solutions made good progress during 2021. The first solution was split in two:

- PJ33 W3-01a, increased flexibility in ATCO validation supported by advanced controller assistance systems, targeting V2 maturity, is actively collaborating with PJ10 W2-73 to ensure proper complementarity;
- PJ33 W3-01b, generic controller validation, has an ongoing target maturity level of V1.

Project **PJ34 W3**, AURA, aims to lay the foundations for the integration of the new entrants to the current and future air traffic environment, developing the required ConOps and validating information exchange between U-space services and ATM systems. The project has the following objectives:

- the AURA project will identify the requirements for information exchange between U-space services and ATM through SWIM and will validate a set of selected U-space services, developing the service definition for the SWIM candidate services;
- the project will define and validate a novel collaborative ATM–U-space ConOps for drones that goes beyond the existing concepts developed for U-spaces.

In addition, the project will provide inputs to the current regulatory and standardisation initiatives regarding U-space, in which external stakeholders will be closely involved, in the form of an advisory board.

The SESAR JU kicked off PJ34 W3, AURA, in January 2021. Both of the solutions of the project showed very good progress during the reporting period. Regular meetings with the PJ34 project team were held to ensure proper mutual understanding in the new U-space era for an IR project.

Despite COVID-19, the project progressed according to the schedule:

- solution 1 achieved significant progress in the 'design' phase, including the completion of a literature review and an assessment of the state of the art, along with the definition of the portfolio of harmonised U-space services;
- solution 2 finalised its initial concept description, with work started on the initial OSED for V1.

1.4.3.3 SESAR solutions delivery: Release process in 2021

The release process is the process by which the maturity of candidate solutions is assessed. In 2021, release 10 was completed and the majority of the work of release 11 was carried out, with the last activities of release 11 expected to take place in 2022. The outcomes of these two releases are presented in the following subsections.

During 2021, the SESAR JU and its members were supported by the SDSS in the implementation and execution of the processes and procedures required to guarantee consistency in the programme life cycle. The SDSS contributed to the definition of the release 12 plan in identifying the different candidate solutions to be validated and delivered in accordance with the release process. Activities related to the maturity assessment of the candidate solutions were also supported by the SDSS through the delivery and maintenance of the maturity assessment tool together with the organisation of the maturity gates and the preparation of the material required as the inputs and outcomes of the gates. Some features were added to STELLAR system. In particular, the system now enables the schedules for all project to be integrated into the overall programme schedule. This ensures consistent development of interdependent projects and provides different users with different views on planning, deliverables' assessment, maturity gates and release delivery.

1.4.3.3.1 Release 10 outcome

Release 10 was executed following the release 10 plan endorsed by the Programme Committee in September 2020. When endorsed by the Programme Committee, the release 10 plan initially covered 22 SESAR solutions that were expected to reach the following maturity levels:

- six SESAR solutions expected to achieve V1/TRL2;
- 11 SESAR solutions expected to achieve V2/TRL4;
- five SESAR solutions expected to achieve V3/TRL6.

In addition, the release 10 plan covered two VLD projects (AAL2 and PJ31) that planned their DEMO gate during Release 10 time frame.

However, during the release 10 life cycle, the scope of release 10 evolved, with the following major changes in terms of the scope of the release 10 plan.

- Owing to the difficulties resulting from the COVID-19 crisis, a number of maturity gates were delayed to release 11:
    - PJ04 W2-28.2, collaborative management of regional airports (V1);
    - PJ01 W2-06, advanced rotorcraft operations in the TMA (V1);
    - PJ01 W2-08a2, automatic CTA for management of arrival in en route and on the ground operations (V1);
    - PJ14 W2-81b, long term A-PNT – enhanced DME (TRL2);
    - PJ02 W2-17.1, improved capacity and safety of runway operations at secondary airports in low-visibility conditions (the cancellation of a number of validation activities was finally recommended in order to target V2 at the end of wave 2);
    - PJ02 W2-21.2, enhanced guidance assistance to airport vehicle drivers combined with routing (V2 gap analysis; note that this solution will be integrated into PJ02 W2-21.3);
    - PJ02 W2-21.3, digital surface management for airport vehicles (V2 gap analysis);
    - PJ02 W2-21.4, full guidance assistance to mobiles using 'follow the greens' procedures based on airfield ground lighting (aprons/taxiways/runways) (V2 gap analysis);
    - PJ02 W2-21.5, enhanced safety in low-visibility procedures through the use of dynamic virtual block control (V2 gap analysis);
    - PJ02 W2-21.6, advanced automated assistance to controllers for surface movement planning and routing (V2 gap analysis)
    - PJ13 W2-115, IFR RPAS accommodation in airspace classes A to C (V2 gap analysis).
- PJ02 W2-17.2, improved approach procedures at secondary airports in low-visibility conditions, will be focused on the development on airborne enablers only, changing the solution nature

from ATM to being technological in nature, and will target TRL4 (instead of the initially planned V3) by the end of wave 2. The decision was taken because of the remaining V2 gaps from wave 1 (PJ02-06 did not complete V2 as expected), but mainly because of delays in SBAS multiconstellation dual-frequency developments (related to the European Geostationary Navigation Overlay Service (EGNOS), Galileo, etc.).

- PJ18 W2-88, trajectory prediction service, initially planned to reach the TRL2 maturity gate, but this will be transformed into an intermediate maturity level in order to de-risk the solution delivery at the end of wave 2.
- PJ18-06b, tactical and NM trajectory performance improvement, was split into two solutions – PJ18-06b (tactical trajectory improvement using ADS-C) and PJ18-06b1 (NM profile improvement using ADS-C) – to better reflect the different maturity levels of these aspects.
- The AAL2 demonstration project delivered two V3 solutions (119 and 120). Release 10 also represented the opportunity to consolidate the results obtained by PJ25 (XSTREAM cross-border SESAR trials for enhanced arrival management) in release 09 into two additional V3 solutions (PJ25-01 and PJ25-02).

Table 3 provides information on the solutions that progressed in maturity during release 10, including six solutions that successfully reached the stage of industrialisation and deployment.

Table 3: Outcomes of release 10

Solution number	Solution name and description	Target maturity level
	High-performing airport operations	
119	**GBAS landing system CAT II operations using GAST-C** The solution improves resilience in low-visibility conditions by enabling GBAS landing system CAT II operations, including CAT II autoland, based on enhanced GAST-C ground equipment. In contrast with GAST-D, in the standard GAST-C, the integrity requirements associated with the detection of anomalous ionospheric conditions that could induce an erroneous GBAS position outside the protection levels (and therefore go undetected by the system) are not monitored on board. Instead, with the enhanced GAST-C ground station, they are monitored on the ground and, when the GBAS position is properly bounded, CAT II operations can be performed (this is referred to as GAST-C service level B). When the integrity levels are not fulfilled, for example in severe anomalous ionospheric conditions, protection levels are inflated and only CAT I operations are supported (this is referred to as GAST-C service level A). The aircraft needs to be equipped for GAST-C but does not need to be equipped for SBAS. SBAS messages are used on the ground in order to monitor the integrity of the GAST-C service. From the ATC perspective, CAT II operations based on GAST-C service level B are the same as CAT II operations based on GAST-D, except that an approach category indication (GBAS landing system CAT I/II) is needed. As for GAST-D availability, GAST-C GBAS availability levels will be broadcast in the automatic terminal information service. If the automatic terminal information service	V3 completed

Solution number	Solution name and description	Target maturity level
	has not yet been updated after a service-level change, ATCOs will pass the information directly to pilots. From the flight crew perspective, CAT II operations based on GAST-C are the same as CAT II operations based on GAST-D. However, with GAST-C, there is no possibility of being alerted to on-board service-level degradation, as can happen in GAST-D, as, in GAST-C, information on service-level degradation will always come from ATC. **Performance benefits** The solution validated both fuel/CO_2 (airlines) and capacity (ANSP/airport) benefits for operations down to CAT II minimums when using GAST-C / CAT I equipment	
120	**EFVS to land using visual infrared** The solution provides an EFVS for landing operations supported by infrared and visual-based technology. The solution allows the pilot to descend below decision altitude / decision height and to land at a runway visual range as low as 300 m without the need to transition to natural vision. The EFVS comprises a head-up system (or equivalent head-wearable display) and a multispectral camera that has the capability to see further ahead than the naked eye in degraded weather conditions. This capacity of the EFVS to provide a significant visual advantage in fog or snow at decision altitude / decision height will enable successful landing, something that would be not possible otherwise. The solution can be deployed in the near future thanks to the new EU all-weather operations regulation from EASA (notice of proposed amendment 2018-06 on all-weather operations), and some aircraft manufacturers have already been certified by EASA. **Performance benefits** This solution allows pilots to land at any airport in adverse weather conditions, and not just at airports that are fully CAT II/III equipped, of which there are relatively few. The strength of this solution is that it relies on advanced aircraft capacity provided by technology, rather than on costly aerodrome infrastructure. The solution would allow aerodromes to remain accessible in more than 78 % of the limiting weather conditions they faced in 2008–2018	V3 completed
 Advanced air traffic services		
PJ25-01	**Collaborative decision-making between airports, TMAs and ACCs for overlapping arrivals managers** The solution aims to balance demand for E-AMAN services with ATCO workload in order to make the best use of the available ACC / upper area control centre (UAC) resources. Information regarding the demand for / availability of the arrivals manager service is shared, via a portal, between TMAs/airports and ACCs. With the advent of multiple E-AMAN operations in the core area of Europe, it will become necessary to coordinate such operations, especially between ATS units and the E-AMAN units.	V3 completed

Solution number	Solution name and description	Target maturity level
	The solution increases the situational awareness at airports by providing information on the current arrival situation and a collaboration platform that incorporates a multilateral communication mechanism to facilitate information-sharing and decision-making, thus enabling the application of E-AMAN strategies. These E-AMAN strategies are defined and prepared per flow regarding sector airspace design, coordinated through a collaborative decision-making process between all ATSUs involved, and activated per flow and per period of time when required. **Performance benefits** The solution enables better management of the increased workload in ACCs (and of the potential negative impact on capacity) that is expected when multiple E-AMAN units are fully operational (from 2024 onwards, as required by the CP1 regulation). The results obtained lead to the following conclusions: • safety – the application of the E-AMAN strategies allows safe operations to be maintained; • capacity – the application of E-AMAN strategies allows the available capacity to be exploited while maintaining E-AMAN operations to the highest degree possible	
PJ25-02	**Target time-of-arrival management for seamless integration of out-of-area arrival flights** The solution optimises target time-of-arrival (TTA) management at airports to better integrate out-of-area inbound flights. TTAs for long-haul flights departing from airports outside the European regulation area are computed by the FMP at the arrival TMA relative to the estimated times of arrival provided by the FOC before departure, for the aircraft to adjust its take-off time. Once the aircraft is airborne, the FMP at the arrival TMA receives a new TTA though the FOC. If needed, a revised TTA is sent by the FOC to the aircraft to enable the pilot to adjust the aircraft speed in flight. The NM remains in the loop throughout this process, thereby ensuring that the network always has the most up-to-date information from long-haul flights: • estimated “time overs” or time over specific points received from long-haul flights outside the initial flight plan processing system zone are sent via a business to business (B2B) uplink channel to the NM to update flight profiles; • target time overs are sent via a B2B uplink channel to update the enhanced tactical flow management system flight profiles and to provide the NM with full awareness of the airport targeted landing sequence; • archive flight data from the NM are retrieved via B2B downlink to establish a post-analysis treatment and presentation for statistics and analysis purposes. Note that out-of-area flights are flights departing from airports outside the European regulation area and arriving at European regulation area airports. **Performance benefits**	V3 completed

Solution number	Solution name and description	Target maturity level
	The solution demonstrated the following benefits: • predictability – improved for the FMP and supervisors; the predictability of long-haul flights also improved when using the time estimates directly from flight crews; • safety – all of the trials were performed while maintaining a high safety level and with no incident reports; • flexibility / AU support / service – the integration of AUs' preferences can ensure that their aircraft is streamed in order to arrive prior to an airport curfew or immediately after the airport has opened; • environment – the environmental benefits of this concept are important, because it applies to long-haul aircraft, which burn more fuel than short haul; in the Zurich demonstration, the average flight time from the entry waypoints was reduced by an average of 40–110 seconds compared with the reference (depending on the waypoint)	
PJ10 W2-96	**UPMS** The objective is to ensure a complete and instant personalisation of workstations depending on each ATCO's operational needs, requirements and preferences so that, for instance, ATCOs will be prevented from overlooking potential misalignments of key functionalities or tools. Additionally, the UPMS will also eliminate the currently existing risk of distraction of ATCOs' attention from the operational situation due to the need for customisation. The concept consists of two main packages: the identification (authentication) system and the UPMS configuration system. **Performance benefits** The solution improves ATCO productivity through new HMI interactions that increase automation and reduce ATCO actions. Validation results showed a decrease of ATCOs' workload by 28 % and an increase in situational awareness by 20 % while using the UPMS, in comparison with the manual setting of HMI – leading to safety and performance increases. Note that the Swiss ANSP Skyguide has already implemented and deployed an operational UPMS in the en route and approach environments	TRL6 completed
PJ18 W2-53b	**Improved performance of conflict detection and resolution tools enabled by reduced trajectory prediction uncertainty** This solution addresses the improvement of conflict detection and resolution tools that are derived from the improvement of ground trajectory prediction with the use of advanced data from ATN baseline 2 ADS-C report messages (as defined in the EUROCAE standards ED228A and ED75C) and improved MET data. The improvements of ground trajectory prediction in PJ18 W2-53b address the use of ADS-C data beyond the items that were studied in wave 1 (gross mass, speed schedule, top of climb and top of descent altitudes, and the predicted speeds at route points), to address in particular the use of the	V2 completed

Solution number	Solution name and description	Target maturity level
	extended project profile (EPP) to calibrate the base of aircraft data (BADA) performance model, improvements in the calculations of turning manoeuvres thanks to the use of turn radius and the turning strategy (overfly versus fly-by), and the implementation of catch-up manoeuvres (not depending on EPP data). **Expected performance benefits** Performance benefits include improvements in cost-efficiency (ATCO productivity), safety and predictability	
	Enabling aviation infrastructure	
PJ14 W2-100	**SWIM technical infrastructure purple profile for air–ground safety-critical information-sharing** SWIM technical infrastructure purple profile for air–ground safety-critical information-sharing allows the distribution of safety-critical information through air–ground SWIM infrastructure ATN/IPS networking, rather than legacy point-to-point contracted services. **Expected performance benefits** The solution supports ATM operational improvements that depend on air–ground information exchange to improve situational awareness and collaborative decision-making, with a focus on safety-critical information. The solution contributes positively to global interoperability by designing and validating an innovative and open standards-based solution for the integration of the aircraft into the SWIM 'network', ensuring that safety and security requirements are met	TRL2 completed
PJ18-02b	**ATC–ATC flight object interoperability** The solution achieves flight object (FO) interoperability between ATC systems (ground-to-ground interoperability; IOP) ATC systems encompasses en route ATC and TMA ATC). ATC–ATC interoperability will consider seamless coordination, also encompassing more complex coordination dialogues requiring negotiation between controllers across ACC boundaries. **Performance benefits** ATCOs and operational experts were able to assess the principles of the FO interoperability concept and confirmed its overall acceptability concerning the following topics: • the improvement of interoperability over online data interchange (the current system); • increased situation awareness; • seamless operations (e.g. changes of route spanning several centres); • expectations that conflict detection and resolution tools will benefit from IOP data	TRL6 completed
PJ18-02b1	**NM–ATC FO interoperability (NM FO IOP)**	TRL4 not completed

Solution number	Solution name and description	Target maturity level
	FO IOP between ATC systems and the NM includes the creation, distribution and update of the FO by the NM, as well as the use of the FO by the NM. While the operational use cases developed for the NM are a useful baseline for future activities, very limited technical work was undertaken and no actual validation activities were performed. The activity was limited to expert groups involving the NM and ATC operational experts who were able to discuss eight use cases allowing the drafting of the operational requirements driving these exchanges. **Expected performance benefits** The solution aims to improve interoperability and safety, and supports further operational benefits, for example increased airspace capacity	
PJ18-06a	**ATC planned trajectory performance improvement** The aim of this solution is to improve trajectory prediction and management using new ADS-C reports and new surveillance parameters. Detailed flight plan information from the FOC (FIXM) will be analysed and used to complement aircraft information. Work on the use of surveillance data, conducted by partner ANS-CS Soft, achieved all of its validation objectives and showed benefits in the technical validation. Although the use of ADS-C and extended flight plan gave positive results, the solution partners concluded that they had yet to demonstrate statistically relevant improvements in the trajectory prediction performance before transitioning to industrialisation and deployment. However, the results of the various exercises that were carried out provided enough confidence to continue validations of the trajectory prediction enhancement and the use of the enhanced trajectory prediction output for tools as part of the wave 2 validations (in project PJ18 W2). **Expected performance benefits** The solution aims to provide operational benefits such as improved predictability and fuel efficiency in other ATM solutions	TRL6 not completed
PJ18-06b	**Tactical trajectory improvement using ADS-C** The tactical trajectory prediction underpins the tactical decision tools, which are a key enabler to realising the benefits of TBOs. The tactical tools exist to support medium-term decision-making and are built on a high-resolution trajectory prediction algorithm with a relatively short prediction horizon of up to 30 minutes. This solution studies improvements to the ATC tactical trajectory using ADS-C information from both simulated flight data and collected live flight data. **Expected performance benefits** The solution aims to provide operational benefits such as improved predictability and fuel efficiency in other ATM solutions	TRL4 completed
PJ18-06b1	**NM profile improvement using ADS-C** ATFCM and early ATC planning rely on the trajectory computed by the NM systems. In order to get to the best possible trajectory, the NM fuses data from different sources (e.g. correlated radar data and ATC system-computed trajectories at activation). The airborne trajectory is considered another	TRL4 not completed

Solution number	Solution name and description	Target maturity level
	important source of information to use in order to further improve the trajectory. This solution studies the possible improvements brought by the ADS-C report data elements in order to improve the NM profiles. While NM systems showed a high level of readiness to accept ADS-C report elements as an additional data source in computing and updating NM profiles, the limited number and representativeness of the validation exercises did not allow conclusions to be made on the benefits or risks linked to the use of ADS-C in the NM. Further study will be required to complete TRL4 in PJ18 W2. **Expected performance benefits** The solution aims to provide operational benefits such as improved predictability and fuel efficiency in other ATM solutions	

In addition, two VLD activities were performed in the release 10 time frame.

According to the close-out report the following solutions successfully completed the maturity gate:

- 1 SESAR Solution expected to achieve V1/TRL2;
- 2 SESAR Solutions expected to complete V2/TRL4;
- 6 SESAR Solutions expected to complete V3/TRL6.

The project **PJ31** (DIGITS, initial trajectory information-sharing) has completed the demonstration activities planned for wave 1. PJ31 (together with the DIGITS-AU project) aimed to demonstrate the ATM benefits that can be realised using downlinked 4D trajectory data (e.g. EPP in ground systems). DIGITS activities considered commercial flights that downlinked ADS-C data to be processed in ATM ground systems of participating ANSPs, which together covered a substantial part of European airspace and air traffic under a variety of operational conditions. DIGITS contributed to bridging the gap between the early validation of the TBOs concept achieved in SESAR 1, also known as 'initial 4D', with successful flight trials in 2012 and 2014, and the deployment of initial trajectory information sharing (i.e. CP1).

The main conclusions of these activities are as follows.

- While DIGITS and DIGITS-AU have demonstrated the feasibility of the airborne use of certified ATS baseline 2 equipment, they have highlighted the challenges in term of crew certification and training that such an endeavour involves for airlines.
- ADS-C dialogues
    - In the preoperational environment, ADS-C dialogues could be successfully established for a vast majority of the flights and have shown a high degree of stability.
    - In the test set-up, the contract establishment required a log-on from the crew. When a log-on was received, ADS-C dialogues were established by the partners when the aircraft was entering its 'area of interest'. The reconnection strategy had a major impact on the number of ADS-C dialogues established with a given flight.
- Ground usage
    - In the Maastricht UAC preoperational set-up, despite the need for further fine-tuning of the HMI and the discrepancy algorithm, the trial provided evidence showing that full operations can be achieved with the current implementation. It should be noted that the

Maastricht UAC trial was limited to upper area operations and that a basic discrepancy algorithm was implemented.
    - The early ground uses (visualisation and conformance monitoring) of ADS-C data on the ground in shadow mode show encouraging results in terms of the usefulness of the EPP information and its positive influence on situational awareness, safety and predictability. However, substantial further developments are still required before industrialisation, for example to understand the impact on workload planning and to increase acceptability for operational use. It should be noted that the shadow mode trials used a more advanced discrepancy algorithm with further enhancements than the basic algorithm used by the Maastricht UAC.
    - In trajectory prediction, the EPP data can be used to calibrate the performance model (BADA) to improve prediction accuracy.

- Bandwidth usage and ADS-Cs
    - The ADS-C report size (and hence the bandwidth usage) is a function of the contract definition, namely the data elements included and their parameters.
    - The main contributor to the ADS-C report size is the EPP data element, whose length is directly proportional to the number of points in the profile.
    - Because it was not considered an objective of PJ31, these data should be used to further validate studies on the required data link bandwidth capacity.

- Data collection and processing
    - A large amount of ADS-C data was collected during the project. However, the data collection has been maintained and will be used for future work. Data collection is required to monitor the infrastructure and to prove its compliance, to show the significance of the demonstration, and to support the development of ground tools using ADS-C data. The collected data require further processing before being used for analysis.
    - Many analyses were conducted in DIGITS. Many additional analyses can be (or should be) carried out, as the data collected are central to supporting further research.

1.4.3.3.2 Release 11 execution

When endorsed by the Programme Committee, the release 11 plan initially covered four SESAR Solutions that were expected to complete the following maturity levels. However, these been increased to absorb the impact on release 10 activities of the COVID-19 crisis (see Section 1.4.3.3.1). The following six ER projects will have activities completed in the release 11 time frame:

- ITACA is targeting TRL1 in 2022;
- safety and resilience guidelines for aviation (FARO) is targeting TRL1 in 2022;
- travel information management for seamless intermodal transport (TRANSIT) is targeting TRL1 in 2022;
- ICARUS is targeting TRL2 in 2022;
- FMPMet is targeting TRL2 in 2022;
- software defined networking architecture augmented with AI to improve aeronautical communications performance, security and efficiency (SINAPSE) is targeting TRL2 in 2022.

Table 4 provides information on the solutions that are expected to progress in terms of their maturity level during release 11.

Table 4: Planned outcomes of release 11

Solution number	Solution name and description	Target maturity level
	High-performing airport operations	
PJ02 W2-21.3	**Digital surface management for airport vehicles** Enhancement of surface management at airports according to higher implementation levels of A-SMGCSs requires that all actors, including vehicles, behave as nodes of a unique, complex airport system and seamlessly exchange all information to be finally consumed by human actors. Data link processes and technologies offer streamlined and error-proof digital means for creating such a communication channel between tower controllers and vehicle drivers, both for traffic separation purposes and for guidance, even in demanding traffic or adverse weather situations. The solution exploits the extension of data link-based information-sharing of requests, order and assigned mission (route) operations to vehicles management. Vehicles are seen as additional users of the control and guidance services, and this solution supports ATCOs and drivers in challenging operating environments such as peak hours and/or low-visibility conditions. Routes can be consumed on board the vehicle so that vehicle drivers can have constant visual access to mission information in a digital format. The foreseen benefits are lower communication workloads on the ATC frequency, the ability to simultaneously handle different dialogues and a reduced probability of miscommunication, increased situational awareness of all human actors and increased safety. **Expected performance benefits** The solution is expected to improve safety, efficiency and human performance	V2 (maturity gate planned in 2022)
PJ02 W2-21.4	**Full guidance assistance to mobiles using 'follow the greens' procedures based on airfield ground lighting (aprons/taxiways/runways)** This solution automates the prioritisation of mobiles along their cleared route in the whole airport movement area. The guidance service takes into account other traffic to guide the mobile as it progresses along its assigned route and at the holding points. It allocates priorities between mobiles based on local operating rules (e.g. runway exit versus parallel taxiways, aircraft versus vehicle, aircraft converging or crossing at intersections and taxiways passing close to push-back routes or other taxiways where insufficient wingtip separation exists), as well as known constraints from the surface management system. Automatic guidance is provided using the 'follow the greens' concept on the airfield ground lighting infrastructure. **Expected performance benefits** The solution is expected to increase safety performance in all weather conditions, to improve predictability through guidance and to reduce workload and stress for ATCOs and vehicle drivers.	V2 (maturity gate planned in 2022)

Solution number	Solution name and description	Target maturity level
PJ02 W2-21.5	**Enhanced safety in low-visibility procedures through the use of dynamic virtual block control** The solution makes use of real stop bars and virtual stop bars (VSBs) appropriately placed in the manoeuvring and movement areas (i.e. at any operationally relevant positions) to reduce the size of control blocks while enhancing safety between taxiing aircraft or taxiing aircraft and vehicles in low-visibility conditions. Air traffic controllers select the clearance limit at a VSB position for an aircraft under control and communicate the clearance via either radio or data link. Guidance information towards the cleared VSB position can also be sent by means of a dedicated data link message to equipped aircraft. The assigned VSB position and the guidance information become active for the involved aircraft when cleared by the controller. VSBs can be linked to already existing intermediate holding positions or real stop bars, applicable to any aircraft, and/or to other operationally useful locations, in this case applicable only to aircraft equipped with an airport moving map and a data link application enabling the communication of relevant VSB positions and statuses. The position of the VSBs on the airport surface are published in the aerodrome charts of the aeronautical information publication and can be broadcasted via the automatic terminal information service. The solution improves the overall safety of airport operations, ensures that both air traffic controllers and flight crew improve their situational awareness, and makes the airport system resilient when low-visibility procedures are in place. **Expected performance benefits** The solution is expected to improve safety, efficiency and human performance	V2 (maturity gate planned in 2022)
PJ02 W2-21.6	**Surface route planning and management operations** Efficiency is improved at airports thanks to air traffic controllers being advised on the most suitable ground routes for all mobiles on the movement area (runways, taxiways and aprons) taking into account users' preferences and known constraints (e.g. taxiway closures and aircraft types). The air traffic controller is provided with an automated graphically assisted recalculation of routes upon occurrence of dynamic constraints or in the case of innocuous deviations, therefore expediting the process of clearing traffic on the airport surface, especially in congested situations. The capabilities provide the air traffic controller with assistance in the short-term planning phase (some minutes before the estimated off-block time and the CTA, or before the mission start time for vehicles) and in the execution phase (e.g. for rerouting). **Expected performance benefits** The solution is expected to enable more efficient allocation of airport resources and to have a positive impact on predictability, in terms of reduced variability of surface operations	V2 (maturity gate planned in 2022)

Solution number	Solution name and description	Target maturity level
PJ04 W2-28.2	**Regional airport(s') collaborative management** This solution specifically aims to improve collaboration between different airports and airport stakeholders through the introduction of a simplified or centralised airport operations centre for regional airports. The introduction of an airport operations centre has been shown to improve airport resilience in larger airports. It may be possible to provide similar benefits for regional airports at a lower deployment cost through the use of automation and innovative approaches to information-sharing and by adopting a more decentralised approach. **Expected performance benefits** Expected benefits include improvements in predictability, efficiency, punctuality and resilience	V1 completed
 **Advanced air traffic services**		
PJ01 W2-06	**Advanced rotorcraft operations in the TMA** The solution addresses procedural means (e.g. RNP 0.1) and technical capabilities (both ground and airborne sides) of IFR rotorcraft operations, assuming that these are supported by dual-frequency multiconstellation GNSS technologies in order to improve access at several rotorcraft-suitable locations in high-density / constrained TMAs, including airports close to dense urban areas (e.g. the edge of a city, a hospital helipad, congested and hostile environments, etc.). This also covers technical performance improvements, which create the potential for enhancing pilot's and ATCO's situational awareness, bringing significant operational benefits to the ATM system. **Expected performance benefits** Expected benefits include improvements in human performance, safety and flight efficiency (e.g. the amount of fuel burnt, the flown trajectory, etc.)	V1 completed
PJ01 W2-08a2	**Automatic CTA for management of arrival in en route and on the ground operations** The solution's objective is to investigate the concept of automatic CTA in order to evaluate the implications for both the ground and the airborne sides regarding automation of CTA constraints. The arrival constraints are to be applied in the en route phase, but also in the ground phase for 'in-horizon' airports prior to start-up. **Expected performance benefits** Expected benefits include improvements in human performance, environmental efficiency (e.g. the amount of fuel burnt), airspace capacity and predictability	V1 completed

Solution number	Solution name and description	Target maturity level
PJ10 W2-93	**Delegation of ATM services provision among ATSUs** The delegation of airspace concept applies when one ATSU delegates a portion of its airspace to another ATSU based on a particular condition. The solution will investigate some use cases for the delegation of ATSs and contingency, in conjunction with the use of virtual centre technology when the ATM data service provider is geographically separated from the virtual centre ATSU that provides ATSs to a region of airspace. Based on the new operational opportunities offered by the virtual centre concept, a preliminary set of delegation and contingency uses cases have been selected, with the aim of further investigating and developing dynamic airspace configuration and advanced ATFCM capabilities. These will allow a completely new architecture and totally new way to provide ATSs. These use cases will consider the operational procedures and resource management to support static and dynamic delegation of ATSs. Additionally, in the context of the virtual centre, the virtual centre ATSUs may use data services from multiple ATM data service providers. This ability will lead to greater opportunities to provide ATSs, from both a technical and an operational context, leading to flexible use of resources, which in turn leads to improved overall performance. **Expected performance benefits** Expected benefits include improvements in human performance, environmental efficiency (e.g. the amount of fuel burnt), en route and TMA airspace capacity, predictability and cost-efficiency.	V2 completed
PJ13 W2-115	**IFR RPAS accommodation in airspace classes A–C** This SESAR Solution aims to accommodate IFR RPASs in non-segregated airspace in the short term, in accordance with the drone roadmap in the ATM aster plan. The main objective of this solution in the release 11 time frame is to ensure that the actions required to bridge the gaps identified during the V2 maturity gate of PJ10-05 in wave 1 are put in place. **Expected performance benefits** The solution aims to improve equity of access to the TMA and en route environments by facilitating the safe accommodation of IFR RPASs in different types of airspace, for example airspace classes A to C.	V2 completed
 **Enabling aviation infrastructure**		
PJ14 W2-81b	**A-PNT – enhanced DME** Aircraft navigate primarily using satellite-based signals, supported by ground-based infrastructure where needed. A prolonged outage of GNSS constellations, such as Galileo, has the potential to limit the ability of aircraft to take advantage of precise PBN procedures, which can have an impact on flight efficiency and airspace capacity.	TRL2 completed

Solution number	Solution name and description	Target maturity level
	SESAR is developing A-PNT as a technical enabler to support PBN/RNP operations in the case of extended GNSS degradation or outage. The solution comprises enhanced DME with the capability to support more stringent A-PNT requirements. The technology is based on coupling the on-board interrogator and ground-based transponder equipment to provide a smooth and seamless implementation path and improved frequency band usage. The enhanced DME is expected to support more stringent RNP and improve spectrum efficiency, for example reducing L-band congestion. It anticipates minimal changes to on-board and ground hardware. The enhanced DME concept was introduced during SESAR 1 following studies carried out by the US FAA and US universities in the last decade. SESAR wave 2 aims to introduce, in addition to the actual range capability (interrogation–reply), a pseudo-ranging (one-way ranging) and to ensure that the additional capability is fully backward compatible in order to support seamless deployment. **Expected performance benefits** The solution aims to achieve the SESAR objectives for service- and performance-based CNS.	
PJ14 W2-84f	**Surveillance performance monitoring – end-to-end chain** Surveillance performance monitoring end to end aims to improve performance monitoring of surveillance systems in line with the performance-based surveillance approach. This solution focuses on the development of surveillance performance monitoring tools for an end-to-end surveillance chain. One of the objectives of the solution is the harmonisation of the tools. Recognising that there is a trend of the standards towards harmonisation, the choice has been made to harmonise the various metric assessment methods. Solution tasks include tools specification aligned with existing and developing surveillance standards, quasi-real-time assessment, the development of tool prototypes and the verification of these prototypes. The results of tools verification are a potential input for the standardisation, in particular the EUROCONTROL specification for ATM surveillance system performance specification. **Expected performance benefits** The solution aims to achieve the SESAR objectives for service- and performance-based CNS.	TRL4 completed

Finally, the STAIRS Demo project will complete an initial set of demonstration exercises, while final results will be consolidated within the release 12 time frame.

1.4.3.3.3 Release 12 planning

The release 12 plan has been endorsed by the Programme Committee and includes all activities under the ER, wave 2 and wave 3 IR, and VLD / open VLD projects that will reach a maturity level between May 2022 and April 2023, inclusive.

Release 12 covers:

- 35 ER projects (16 fundamental science and outreach ER projects and 19 application-oriented ER projects);

- 76 IR SESAR solutions that are expected to reach the following maturity levels:
    - four SESAR Solutions that are expected to achieve V1/TRL2;
    - 37 SESAR Solutions that are expected to achieve V2/TRL4;
    - 35 SESAR Solutions that are planning to achieve V3/TRL6.
- 13 VLD projects (both VLD and open VLD).

The output of release 12 is fundamental to making significant progress towards the completion of phase C of the ATM master plan and, in particular, the airspace architecture study transition plan objectives: 21 solutions in release 12 contribute to the transition plan, 11 of which are expected to achieve V3/TRL6.

1.4.4 Strategic area of operation 4: Delivery of very large-scale demonstration activities

The SESAR JU met all of its objectives related to VLD activities in 2021, as set out in Section III of the SPD for 2021–2023. This includes the following achievements and results.

- The call with reference H2020-SESAR-2016-2 (VLD Open 1 call for proposals) – the delivery of results. All projects were closed for operations.
- The call with reference H2020-SESAR-2019-1 (VLD wave 2) – the execution of the H2020 Reporting – payments (REPA), including the project reviews. The wave 2 call was conducted in 2019 and resulted in the award of three grants for VLD activities, which were in execution in 2021.
- The call with reference H2020-SESAR-2020-2 – the launch of VLD wave 3 projects into execution. The call was launched in March 2020 as planned and resulted in the award of two grants for VLD activities, which were in exection in 2021.
- The call with reference H2020-SESAR-2020-1 – the launch of open VLD2 projects into execution. The call was launched in March 2020 as planned and grant agreements for all six projects on the main list were signed by December 2020. Two additional projects from the reserve list proceeded to the grant agreement phase in December, and grants were signed in January 2021. The projects either delivered their results in 2021 or will do so in 2022.

1.4.4.1 Activities carried out under the Horizon 2020 framework

1.4.4.1.1 Status of the VLD open 1 call projects (call H2020-SESAR-2016-2)

The VLD open 1 call for proposals was opened in 2016 and closed in 2017. It constituted the second work area of the call, which also covered ER3 (see Section I.4.2.1). The resulting projects were launched into execution in 2018. Ten VLD projects resulted from this call for proposals, of which one project, AUDIO, completed its activities and was closed in 2021. The outcomes of this project in 2021 are outlined below.

AUDIO

The VLD project AUDIO, which focused on AU supporting demonstrations of integrated airport operations, aimed to demonstrate that the safety and efficiency of aircraft movement on the airport surface could be increased by implementing an innovative, advanced and connected moving map application for electronic flight bag applications. The technology was expected to be tested in an on-board demonstration at Hamburg Airport. The application should have provided the cockpit with local airport data such as data on the on-ground traffic situation and planned taxi routes. Equipped with this additional information, on-board operations were expected to run more smoothly, as crews would have been aware of the planned ground trajectory and the surrounding complex environment. This would have also allowed crew members to react more easily to last-minute replanning of routes once the aircraft was off-block. This should have resulted in a safer sequence, a more reliable targeted take-off time, less complexity for the crew, more efficient taxiing and fewer emissions because fuel consumption would have been reduced.

In 2021, the COVID-19 pandemic continued to affect the project, preventing any progress from being made on the different activities. Therefore, the grant was terminated early, at the end of October 2021, without any significant scientific results being delivered.

1.4.4.1.2 Status of VLD projects under the wave 2 call (H2020-SESAR-2019-1)

The wave 2 call for proposals with reference H2020-SESAR-2019-1 ([33]) was conducted in 2019. It resulted in the award of three grants for VLD activities, amounting to a total value of EUR 12 373 554, and the launch into execution of the corresponding projects. These projects expected to deliver their results from 2020 to 2022. The following sections provide information on the projects' activities in 2021.

DREAMS

Project VLD01-W2, the demonstration of runway enhanced approaches made with satellite navigation (DREAMS), started on 1 October 2020. Its focus is on enhanced arrival procedures supported by advanced GNSS navigation technologies (GBAS CAT II/III) to reach V3/4 maturity. This is achieved through a proof of concept combining commercial and non-commercial flights with flight trial tests. The demonstration covered business jets, commercial (Airbus) aircraft and commercial operators or flight test aircraft. Three types of operations are covered (IGS, SRAP and IGS-to-SRAP), including a pioneer flight on GBAS GAST-C+ for CAT I/II and GAST-D for CAT II/III. Adaptive IGS-related work are limited to technical studies. In comparison with typical arrival procedures, enhanced arrival procedures encompass:

- steeper operations, namely IGS;
- staggered threshold / additional point operations, namely SRAP;
- a mix of IGS, SRAP and IGS-to-SRAP.

In addition, the DREAMS project is addressing adaptive IGS reviewing procedural aspects and, if deemed necessary, will perform tests using aircraft simulators.

The project continued operating throughout the COVID-19 crisis, but the crisis had some significant impacts, which risked the closure of the project. Finally, the principles of the objectives were maintained through the replacement of the Milano Malpensa Airport exercises with Enschede Airport Twente exercises.

It was agreed that the SRAP objectives would be transferred to the Twente exercises. The Twente validation exercises were improved through:

- a noise benefits analysis,
- a human performance and safety analysis;
- the participation of commercial aircraft to support the evaluation of SRAP (TUI Fly Nederland and Lufthansa).

Additionally, a new validation increased second glide slope exercise would also be carried out at Twente, where a dual precision approach path indicator would be tested (safety and human performance analysis).

Activities to prepare the validation exercises at the Frankfurt, Roma Ciampino and Twente airports were carried out during this period, with no blocking issues. The project delivered a revised demonstration plan in 2021.

STAIRS

([33]) The call conditions were set out in the SESAR JU annual work programme for 2019. The call documentation is available on the European Commission's Funding and Tenders Portal.

Project VLD02-W2, surface traffic alerts improve runway safety (STAIRS), kicked off in February 2020. The project focuses on supporting the transition from R&I to deployment for PJ03b-05 (traffic alerts for pilots for airport operations), which achieved V3 in release 9.

The solution validated two different implementations.

1. Mainline aircraft implementation. The surface traffic alerts on runways for pilots without traffic display and warning alerts only (SURF-A) consist of an on-board system that detects the risk of collision with other traffic during runway operations and provides the flight crew with aural alerts (mostly at the 'warning' alert level).
2. Business aircraft implementation. The surface traffic alerts and indication on runways for pilots with optional display, caution and warning alerts (SURF-ITA) consist of an on-board system that detects potential and actual risks of collision with other traffic during runway and taxiway operations and provides the flight crew with visual and aural alerts (indication, caution and warning alert levels).

The demonstration activities in VLD02-W2, STAIRS, target a large number of commercial flights at many high-, medium- and low-density airports to demonstrate the system performance. The activities should be performed in partnership with European airlines and during business jet operations in line with the KPAs identified, such as safety and human performance defined by the European ATM Master Plan.

The project's specific objectives are to:

- support a controlled entry into service of SURF-A and SURF-ITA by demonstrating the required safety objectives for the certification of the new functions to the airworthiness authorities;
- replay the data collected in fast-time simulations to further assess the performance of the new functions and fine-tune the related algorithms;
- assess the quality of the collected ADS-B data, supporting the intention to establish a worldwide reference for Automatic Dependent Surveillance–Broadcast (ADS-B) quality on the ground;
- ensure interoperability between the on-board safety nets provided by PJ03b-05 and those available to the other ATM stakeholders, in particular ATCOs providing tower ANSs.

In 2021, the project team continued to work on the planning of the demonstration activities, from the operational, technical and regulatory perspectives. These activities experienced significant delays induced by the COVID-19 pandemic and changes in Airbus's business priorities. However, the objectives of the projects are still considered feasible in the time frame of the grant agreement.

SORT

Project VLD03-W2, safely optimised runway throughput (SORT), kicked off in July 2020. It aims to demonstrate the operational and technical readiness of the following mature SESAR solutions to transition to industrialisation and deployment:

- PJ02-01-01, optimised runway delivery on final approach;
- PJ02-01-04, wake turbulence separations (for arrivals) based on static aircraft characteristics;
- PJ02-01-07, reduction of wake turbulence risk considering acceleration of wake vortex decay in ground proximity;
- PJ02-03, minimum-pair separations based on required surveillance performance;
- PJ02-08-01, trajectory-based integrated runway sequence;

- PJ02-08-02, trajectory-based integrated runway sequence;
- PJ02-08-03, increased runway throughput based on local runway occupancy time characterisation.

In 2021, the project team continued planning the following demonstration activities, from the operational, technical and regulatory perspectives:

- the demonstration of RTSs supported by preoperational hardware and software as part of solutions PJ02-01-01, PJ02-01-04 and PJ02-03 at London Heathrow Airport;
- the demonstration of live operations at Vienna Airport as part of solution PJ02-01-07, focusing on technical and regulatory constraints;
- the demonstration of shadow mode as part of solutions PJ02-08-01, PJ02-08-02 and PJ02-08-03 at Stockholm Arlanda Airport.

In addition, the project progressed in the preparation of the operational concept, regulatory aspects, guidance, benefits and issues associated with reducing the surveillance separation minimum for in-trail pairs on final approach at Zurich Airport, including revised runway occupancy time aircraft categorisation.

The COVID-19 pandemic affected the project, forcing a demonstration initially planned at Zurich Airport to be merged with the Heathrow demonstration and delaying most of the project tasks. However, the objectives of the projects are still considered feasible in the time frame of the grant agreement.

1.4.4.1.3 Status of the VLD open 2 call (H2020-SESAR-2020-1)

The VLD open 2 call for proposals with reference H2020-SESAR-2020-1 ([34]) was defined using the priorities set out in the European ATM master plan, and in particular in the essential operational changes set out in the 2020 edition of the European ATM Master Plan. It also considers the operational and technical measures that need to be implemented in the very short term (2020–2025), as outlined in the airspace architecture study transition plan. The open call was opened at the end of January 2020 and the call deadline was postponed to the end of June because of COVID-19. The total budget of the call was EUR 21 933 376. Following the evaluation process, which took place in September 2020, a main list and a reserve list were drawn up. Grant agreements for all six projects on the main list were signed by December 2020. Two additional projects from the reserve list proceeded to the grant agreement phase in December, and grants were signed in January 2021. The projects will deliver their final results in 2022.

The following sections provide information on the projects' activities in 2021.

ALBATROSS

The VLD project ALBATROSS, the most energy-efficient flying bird, aims to explore the possibilities of implementing and supporting flights with zero waste in terms of fuel and CO_2 emissions, and to demonstrate, through a series of live trials, the feasibility of minimising the fuel consumption of flights in various operating environments. The aim is to achieve fuel consumption as close as possible to the theoretical optimum and as low as possible compared with the average historical fuel consumption of similar aircraft types operating on the chosen city pairs under similar operational conditions. The calculation of optimal flight trajectory should aim to achieve, as far as possible, zero waste fuel and

([34]) The call conditions were set out in the 2019 work programme section of the SESAR JU's SPD for 2019–2021. The documentation is available on the Funding and Tenders Portal.

CO_2 emissions, and takes into consideration available information on weather conditions during the planning and execution of the flight.

ALBATROSS follows a holistic approach by covering all flight phases directly involving all relevant stakeholder groups (e.g. airlines, ANSPs, the NM, airports and industries) and addressing both operational and technological aspects of aviation and ATM. The project will demonstrate the complementarity of solutions, for example the use alternative aircraft fuel combined with improvements to ATM and AUs' operations on the ground, in the TMA and en route. To foster increased flexibility and scalability, the demonstrated approaches will also leverage cutting-edge technologies such as modern methods of air–ground connectivity and novel highly collaborative ATM.

The project's key objectives are to:

- develop a coherent generic 'zero fuel and CO_2 emissions waste flight' ConOps (WP2), aligned with the SESAR;
- undertake trial activities (WP3) to demonstrate the principles defined in the ConOps for preferred green flights, including flights adopting SESAR Solutions that enable fuel efficiency gains;
- undertake identical performance assessments (WP4) of all demonstrations to ensure that a single methodology and common metrics can be developed for the analysis of all trials;
- disseminate the results (WP5) of ALBATROSS to all interested stakeholders and target organisations, to foster their interest in the project, and to take into account their recommendations in the later stages of the project.

ALBATROSS will be a key element of the sustainability strategy of the SESAR JU, by demonstrating the environmental benefits of the applications of multiple solutions on the same flight, at a large scale. Ideally, the project will trial the concept on approximately 1 000 flights.

The ALBATROSS project started on 1 December 2020. The first ConOps version was submitted and approved along with the demonstration plan that provided details of the different exercises. Updated versions are planned for the beginning of 2022. Other key deliverables that were completed in 2021 were the flight analysis methodology and KPIs calculations. The VLD requested a 6-month extension owing to the impact of COVID-19, which was granted.

ALBATROSS participated in the global Airbus Sustainability Summit, held in September 2021, and was used as an example of a European collaboration project to improve flight operations efficiency.

AMU-LED

The VLD project on air mobility urban – large experimental demonstrations (AMU-LED) aims to design and deliver a detailed ConOps and a definition of urban air missions, followed by simulations and a large real-flight campaign composed of three demonstrations to verify and validate the concepts and to compare two unmanned traffic management architectures. AMU-LED will allow UAM stakeholders to specify various use cases applicable to logistics and the urban transport of passengers, to integrate into the UAM environment, to demonstrate the UAS ground and airborne platforms and, finally, to assess safety, security, sustainability and public acceptance. The flight demonstrations will amount to more than 100 hours of flying in total, and flights will take place across Europe (in three different countries) and using various scenarios. The United Kingdom (Cranfield), the Netherlands (Amsterdam/Rotterdam) and Spain (Santiago de Compostela) have expressed interest in the project and have communicated their needs in terms of air logistics, transport and emergency services.

The SESAR JU kicked off AMU-LED in January 2021. The main deliverables of the project were the demonstration plan, the CDE plan, the operational safety analysis and concept and the initial high-level ConOps.

Workshops were organised to gather information and share the vision with stakeholders.

Demonstration preparation activities are on track, even though the new EASA regulation is making the granting of flight authorisation more complex.

CORUS-XUAM

The VLD project on ConOps for European U-space services – extension for urban air mobility (CORUS-XUAM) will demonstrate how U-space services and solutions could support integrated UAM flight operations, allowing electric VTOLs / UASs and other AUs (unmanned and manned) to operate safely, securely, sustainably and efficiently in a controlled and fully integrated airspace, without undue impact on operations currently managed by ATM.

The activities will start with an update of the U-space ConOps, addressing the integration of UAM/UAS operations into the airspace and identifying new U3/U4 services. The project activities will continue with the preparation and execution of six challenging VLD campaigns in six different European locations. These VLD activities will be at the heart of CORUS-XUAM and will support integrated operations of UASs/UAM and manned aircraft and advanced forms of interaction through digital data exchange supported by integrated and advanced U-space services in urban, suburban and inter-city scenarios, as well as in and near ATM-controlled airspaces and airports. The VLDs will focus on different types of mission, such as passenger transport, logistic, delivery, emergency response and surveillance, using different U-space deployment architectures and state-of-the-art technologies. They will consider coordination between ATC and U-space, including interaction with ATCOs and pilots. The VLDs will combine flights by electric VTOLs with other traffic and operations in the controlled traffic regions of major airports. Vertiport procedures, separation and data services will also be demonstrated. The main results will be used to further consolidate the ConOps at the end of the project. The project will also involve extensive consultation and communication initiatives with reference authorities, U-space stakeholders and end users.

The SESAR JU kicked off CORUS-XUAM in January 2021. During this period, the project focused on the definition of the reference demonstration scenarios and relevant use cases, the definition of more advanced U-space services enabling UAM operations, the consolidation of the U-space ConOps and preparatory activities of the various demonstration activities.

Despite the impact of COVID-19, the project progressed according to the schedule, delivering:

- the project management plan (including the ethical code of conduct),
- the CDE strategy and action plan,
- the demonstration plan.

GOF2.0

Project GOF2.0, which focuses on an integrated urban airspace VLD, aims to securely and sustainably demonstrate the operational validity of serving combined UASs, electric VTOLs and manned operations in a unified, dense urban airspace using current ATM and U-space services and systems. Both ATM and U-space communities depend extensively on the provision of timely, relevant, accurate and quality-assured digital information to collaborate and make informed decisions. The demonstrations focus on the validation of the GOF2.0 architecture for highly automated real-time separation assurance in dense airspace, including precision weather and telecommunications networks for air–ground

communication, and aims to significantly contribute to our understanding of how UAM and other commercial drone operations can be safely integrated into ATM airspace without degrading safety or security or disrupting current airspace operations.

The SESAR JU kicked off GOF2.0 in January 2021. GOF2.0 completed wave 1 validation exercises and executed live trial demonstrations as planned. The GOF2.0 solution integration was successful in supporting the demonstrations. The first wave of trials addressed the complexity of trials through strategic deconfliction. Various scenarios were further developed and included in the execution of live trials to represent a majority of the most relevant use cases for UAM and to illustrate the many possibilities and situations that will arise. The GOF2.0 solution to support the wave 1 validation exercise was set up with common information system (CIS) cloud deployment, U-space service provider and CIS integration, CIS and ATM integration / a collaborative interface with ATC, and a strategic and tactical deconfliction service in a mixed environment.

Demonstration preparation activities for wave 2 are on track, even though the new EASA regulation is making the granting of flight authorisation more complex.

SAFIR-Med

The vision of the VLD project SAFIR-Med, which focuses on safe and flexible integration of advanced U-space services focusing on medical air mobility, is to achieve safe, sustainable, socially accepted and socially beneficial UAM. Five unmanned aerial vehicle platforms (passenger electric VTOL vehicles, hydrogen fuel cell VTOL vehicles, automated external defibrillator medical drones, and X8 medical transport) will be combined with manned aviation in real-life exercises validating technology in an authentic urban environment. The technologies of all partners will be leveraged to make use of the maximum number of U-space services, including an advanced DAA U-space service, with a view to achieving the highest possible operational safety level. The demonstrations will take place in the cities of Antwerp (Belgium), Aachen (Germany) and Heerlen (the Netherlands), leveraging the Maastricht, Aachen, Hasselt, Heerlen and Liège trans-border region, following a full de-risking exercise at the DronePort beyond visual line of sight test facility in Belgium.

The demonstration results will be further virtually enhanced through large-scale simulations in order to test the maximum airspace capacity of the ConOps. The project results will then be further validated and made representable for the whole of the EU, by simulating demonstrations in additional locations in Europe, namely Athens (Greece) and Prague (Czechia). Refinements to the current U-space architecture principles and measurable indicators for UAM will enable smart cities to include UAM in their transport roadmaps, supporting standardisation and, thereby, safety. Finally, SAFIR-Med will make an important contribution to the EU healthcare system, by ensuring that future generations will continue to have equitable access to the best care and treatments.

The SESAR JU kicked off SAFIR-Med in January 2021. During this period, the project actively prepared the demonstration exercises. The project's main deliverables were the DEMOP, the CDE plan, the UAM airspace management report, the geofencing concept report, the agent-based simulation framework and the system specifications and architecture report

Workshops were organised to gather information and share the vision with stakeholders.

Demonstration preparation activities are on track, even though the new EASA regulation is making the granting of flight authorisation more complex.

TINDAIR

The VLD project on tactical instrumental deconfliction and in-flight resolution (TINDAIR) aims to demonstrate the safe integration of UAM as an additional AU. Four missions/flights, with different

operating methods, will take place in coordination with all relevant partners and will involve more VTOL platforms carrying human passengers and medical equipment to simulate the variety of possible U-space users in the near future. The demonstration flights will also include vehicles with full autonomous capabilities for automated safe procedures, as well as helicopters.

Flight demonstrations will address tactical conflict resolution and emergency landing, with a focus on preflight checks for possible conflicts in the strategic phase and in-flight checks to enable each VTOL vehicle operating in that airspace to rely on a DAA service. The DAA service will instruct the aircraft to change its speed, level or heading, as needed, or will force the aircraft to make an emergency landing at a pre-identified vertiport in the urban area.

The ultimate objectives of this project are to deliver strategic and innovative technologies that can drive competitiveness and UAM growth using an impact-oriented approach and to demonstrate the safe integration of UAM aircraft as additional AUs. The results of the TINDAIR project will help to:

- refine the safety, performance, standardisation and regulatory requirements needed to enable UAM, with a focus on U-space U3 services identified in the U-space blueprint and refined by the CORUS-XUAM project;
- unlock new and enhanced applications and mission types in high-density and high-complexity areas.

The SESAR JU kicked off TINDAIR in February 2021. During this period, the TINDAIR project actively prepared the demonstration exercises.

The project's main deliverables were the DEMOP, the CDE plan, the system design document, the safety assessment plan and the social acceptance assessment plan.

Workshops were organised to gather information and share the vision with stakeholders.

Demonstration preparation activities are on track, even though the new EASA regulation is making the granting of flight authorisation more complex.

Uspace4UAM

The VLD project Uspace4UAM (U-space for urban air mobility) aims to bridge the gap between development and deployment. The project will tackle issues of operational concepts, regulation and standards, while building confidence in a safe and orderly integration of UAM in everyday air traffic. A series of well-defined, iterative and multinational demonstrations involving both drones and UAM vehicles will be conducted. They will cover different use cases, including mixed operations, to allow the project to derive critical enablers for a wide set of UAM service applications that can be applied all over Europe.

Uspace4UAM will build on the CORUS-XUAM project results and on operational and business experience already gathered in operational drone service implementations in Europe. It will study safety cases and their impact on system requirements, and will look at how regulation and standardisation can be set up to support innovators to build a sustainable business case while operating safely in a multimodal transport network. In order to prove that this will be achieved, and that the project indeed has built a bridge between development and deployment, the project is set to deliver a number of commercial contracts for the provision of fully automated drone services and to present solutions to identified gaps that need to be addressed before fully autonomous urban air taxi services can be implemented.

The SESAR JU kicked off Uspace4UAM in February 2021. A significant amount of the work was done during this period of the project. In 2021, the Uspace4UAM project actively prepared the five demonstration exercises that will run in 2022.

The project's main deliverables were the DEMOP and the availability notes. The production of the UAM ConOps document is on track.

Workshops were organised to gather information and share the vision with stakeholders.

Demonstration preparation activities are on track, even though the new EASA regulation is making the granting of flight authorisation more complex.

VLD2 VOICE

The project VLD2 VOICE, focusing on reduced separations and improved efficiency based on VHF communications over low Earth-orbiting satellites, explores the use of space-based infrastructure, which is a necessary step towards the provision of ATS in remote areas or large portions of airspace where they are not currently available owing to the geographical constraints of terrestrial-based systems. In such areas, the answer could be to improve the efficiency, safety and capacity of aviation to enable reduced separations minima in remote airspace based on satellite VHF voice and data communications systems. Other satellite-based technologies cannot provide a complete and integrated solution in terms of the performances necessary to reduce separation.

The objective of VLD2 VOICE is to demonstrate that the use of satellite-based VHF systems providing voice and data link communications allows ATS traffic in remote airspace to be handled in the same way as in a continental environment. The project also aims to demonstrate that the current separation can be reduced without compromising safety. In addition, the project will perform some cross-border operations between adjacent flight information regions in different countries. The demonstration will cover operations in the Canarias and Sal Oceanic flight information regions, where ATCOs communicate in real time with aircraft at distances of more than 1 500 km.

The project has progressed well with the submission of the demonstration plan, including the planned exercises to be performed. Good progress has been made on establishing the basis for the technical solution, defining the architecture to be deployed during the next reporting period and providing the definition of use cases to be addressed during the TRL7 demonstration.

In terms of forecasted activities, the project proposes to use a high-altitude pseudo satellite during the first stage of the validation for risk mitigation purposes, and intends to provide an earlier demonstration of the concept. High-altitude pseudo satellite deployment and use will not have any impact on the VLD2 VOICE budget. The project requested a 6-month extension due to the impact of COVID-19, which was granted.

1.4.4.1.4 Status of the wave 3 call (H2020-SESAR-2020-2)

Concluding the wave 3 call for proposals (see Section I.4.3.2), the following two VLD projects were awarded funding: PJ37 W3 (ITARO) and PJ38 W3 (ADSCENSIO).

ITARO

The VLD project PJ37 W3, on integrated TMA, airport and runway operations (ITARO), addresses two topics of the wave 3 call:

- IR activities topic 5 – collaborative management of TMA throughput;
- innovative action (IA) topic 6 – integrated runway throughput and terminal efficiency (VLD-like).

The project aims to:

- complement wave 2 solution PJ07 W2-39 (collaborative framework managing delay constraints on arrivals) by performing validation activities on the collaborative process dealing with delay constraints on arrivals, feeding into solution PJ07 W2-39 V3 R&I activities;
- demonstrate the benefits of integrating the following SESAR solutions:
    - PJ01-05, airborne spacing flight deck interval management,
    - PJ02-01-01, optimised runway delivery on final approach,
    - PJ02-01-04, wake turbulence separations (for arrivals) based on static aircraft characteristics,
    - PJ02-08-03, increased runway throughput based on local runway occupancy time characterisation (ROCAT),
    - solution 05, extended arrival management horizon,
    - solution 11, continuous descent operations using point merge;
- complement wave 2 solution PJ01 W2-08b (dynamic extended TMA for advanced optimised descent operations) by performing additional development and validation activities on the optimisation of the climb and descent phases of a flight, feeding into solution PJ01 W2-08b V2 R&I activities.

The first iteration of the demonstration plan defining RTS 1, involving the integrated arrival management process for TMA operations at Amsterdam Airport Schiphol, has been developed. The initial description of the RTS 2 and the flight test plans definition has also been started. The development of the tools to be used in the demonstrations were initiated.

ADSCENSIO

VLD project PJ38 W3, ADSCENSIO (on how ADS-C enables and supports improved ATM operations), relying on the general principle of TBOs, aims to improve various features of ATC by better anticipating how flights will behave. During the execution of a flight, the important information needed for accurate and reliable trajectory prediction, or alternative scenarios, can be provided by the aircraft itself. This information includes wind conditions and speed schedule or the trajectory prediction computed by the aircraft navigation system itself, based on the four dimensions of horizontal and vertical positions, altitude and time. Some aircraft operated by European airlines already have the capacity to send this information via a data link communication application.

The objectives of the project are to demonstrate both the improvements that can be achieved in many common operational situations that ATCOs need to manage and the efficiency and robustness of a technological infrastructure to support the exchange of trajectory-related information between the aircraft and various ground consumers using data link communications. More specifically, through operational demonstrations of the use of ADS-C and by evaluating the ability of the proposed infrastructure to convey and share ADS-C data, the project aims to:

- continue to collect ADS-C reports and related data sent by aircraft equipped with the technology to downlink flight trajectory information;
- analyse the characteristics, performance and behaviour of ADS-C data from the operational and technical perspectives;
- perform operational evaluations to demonstrate and characterise the benefit of integrating ADS-C data in ATC systems, with a specific focus on the integration of SESAR Solution 115 (ATM Master Plan reference) in the continuity of initial works performed in wave 1 (in particular, projects 10-2a and 18-6);

- demonstrate the feasibility of an efficiently distributed ADS-C service (ADS-C common service) on the ground;
- demonstrate the use of a SATCOM link to complement VHF data link mode 2 technology to ensure air–ground ATN connectivity (SESAR solution 109 in the European Master Plan).

ADSCENSIO started on 1 November 2020. The project has progressed in terms of the development of an initial ADS-C common service infrastructure. In the light of the outcome of PJ31 (DIGITS), ADSCENSIO is essential to the execution of operational evaluations scheduled throughout 2022, and it also paves the way for the standardisation of the main features of such a service, which will be a strong enabler of CP1 mandate deployment while being a means to sustain VHF data link mode 2 network infrastructure.

The project started testing ADS-C exchanges via new SATCOM technology with flight test platforms (Airbus and Honeywell), in order to mitigate the possible delay of having revenue flights in such a configuration.

ANSPs have progressed in the preparation (tools and procedures) of operational evaluations that will take place in 2022. A coordination is starting to be put in place with AUs, as the active participation of operators flying 4D-capable aircraft is key for the demonstration of operational benefits.

The project delivered its second release of the demonstration plan in 2021.

1.4.4.2 Activities carried out under other financial frameworks: Status of the European Climate, Infrastructure and Environment Executive Agency call (CEF-T-2021-SIMOBGEN)

The European Climate, Infrastructure and Environment Executive Agency (CINEA) launched a new call under the CEF in September 2021, containing provisions for a series of SESAR JU digital European sky demonstrators in the areas of green aviation and UAM. The demonstrators are a key tool for supporting the SESAR JU's vision of delivering the Digital European Sky, matching the ambitions of the European Green Deal and the 'Europe fit for the digital age' initiatives. As indicated in the Multiannual Work Programme and in the Bi-Annual Work Programme for years 2022-2023, an indicative budget of up to EUR 60 million is foreseen for the demonstrators, which will run from 2022 to 2025 within the framework of the SESAR 3 JU.

While the grants awarded to the projects are managed under CINEA responsibility, the S3JU will have a central role in steering the awarded projects from a technical perspective to ensure that the demonstration activities and the related outcomes will match the SESAR 3 JU's expectations. The contractual management of the grants will remain under CINEA's responsibility.

The two SESAR-related topics covered by the call – (1) U-space and UAM and (2) an aviation green deal – have been selected from among nine flagships outlined in the draft Digital European Sky SRIA. Published in November 2021, the SRIA serves as the basis for the work programme of the SESAR 3 JU, which was established at the end of 2021.

The Digital Sky Demonstrators will take place in live operational environments and will put to the test (on a very large scale) the technological solutions necessary to deliver the Digital European Sky. The demonstrators are part of an innovation pipeline designed by the SESAR JU to bridge the gap between applied/industrial research and industrialisation, and to accelerate market uptake. Critical to their success will be the involvement of early movers, as well as a strong close connection with relevant standardisation and regulatory activities and bodies.

Connecting Europe Facility SESAR call topics

- **U-space and UAM.** To unlock the potential of the drone economy and to enable UAM on a wide scale, a new ATM framework for low-altitude operations needs to be put in place. Known as U-space, the framework sets out a set of new services relying on a high level of digitalisation and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. As such, U-space is an enabling framework designed to facilitate any kind of routine mission, in all classes of airspace and all types of environment – even the most congested – while addressing an appropriate interface with manned aviation and ATC.
- **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 will be necessary to speed up the modernisation of the infrastructure in order to offer more capability and capacity, making the infrastructure more resilient to future traffic demand and adaptable through more flexible ATM procedures. Furthermore, reducing the impact of aircraft noise and improving air quality will remain a priority around airports.

1.4.5 Strategic area of operation 5: Deliver SESAR outreach

The SESAR JU met all of its objectives related to SESAR outreach in 2021, as set out in Section III of the SPD for 2021–2023. This includes the following achievements and results.

- The strengthening of global interoperability activities aligned with the European Commission's expectations, especially towards the ICAO, in close collaboration with the US FAA / NextGen and other ATM modernisation initiatives. Activities were carried out in accordance with the plan. The SESAR JU participated in the ICAO's Global Air Navigation Plan (GANP) Study Group and agreed a new structure for work with the FAA under the EU–US memorandum of cooperation (MoC).
- The strengthening of links with standards-making organisations such as EUROCAE and the RTCA, with the involvement of SESAR JU members, and making SESAR material available in support of standardisation. Liaison with standardisation bodies took place in accordance with the plan.
- Active cooperative arrangements with all European actors (Member States and regions), international actors and other modernisation initiatives in aviation relating to SESAR definition and development phases. The cooperation activities took place in accordance with the plan.

SESAR outreach plays an integral role in engaging with the wider aviation community and informing them about the SESAR JU's work and results. The outreach also encourages wider international commitment to the SESAR approach to ATM modernisation, and contributes to maintaining the momentum around SESAR R&I.

For 2021, the following key messages were the focus of the SESAR JU's outreach activities:

- the unique SESAR JU public–private partnership is delivering solutions that drive aviation performance, in support of EU transport and mobility policy objectives;
- the SESAR JU model pools resources and expertise from Europe's aviation community and beyond to deliver efficient and value-for-money R&I;
- embracing new trends and opportunities through cutting-edge R&I is a prerequisite for maintaining Europe's global leadership and competitiveness in aviation.

1.4.5.1 Cooperation with non-EU countries and international organisations

The SESAR JU's strategy for cooperation with non-EU countries and/or international organisations, pursued in the framework of the EU's sustainable and smart mobility strategy and in close coordination with the European Commission, aims to secure SESAR's position as a global leader in ATM modernisation in support of the ICAO's GANP, promoting SESAR Solutions for global interoperability and harmonisation, and thereby supporting EU industrial leadership and competitiveness. The SESAR JU's ability to pursue these objectives during 2021 was significantly affected by the situation created by the COVID-19 pandemic, which resulted in many countries, as well as the ICAO, focusing attention on addressing the crisis affecting aviation and the essential task of promoting recovery. International travel continued to be heavily disrupted during 2021 and, therefore, the SESAR JU's engagement with international partners was severely curtailed.

That said, the SESAR JU nevertheless participated in a number of activities at ICAO level during 2021. This included the GANP Study Group, which oversees the future evolution of the GANP and is laying the groundwork for a major update in 2025. The SESAR JU participated actively in the ICAO UAS Advisory Group, helped to organise the ICAO's annual Drone Enable event and contributed significantly to the development of the ICAO's UAS framework document, building on experience gained in SESAR U-space projects. The SESAR JU also participated in discussions in the ICAO UAS Flight Rules Task Force, led by the IATA. Finally, the SESAR JU participated in the ICAO's Integrated Communications, Navigation, Surveillance and Spectrum Task Force, which aims to further develop the CNS systems roadmap and frequency spectrum access strategy in a performance-based and service-oriented manner.

The SESAR JU also continued to contribute to the ICAO's technical work on the exploration of the feasibility of a long-term global aspirational goal for international civil aviation CO_2 emission reductions, through its Committee on Aviation Environmental Protection (CAEP). The SESAR JU acted as co-lead of the operations subgroup of CAEP's Long-Term Aspirational Goal Task Group, bringing its work to completion in late 2021 as part of the task group's report to CAEP.

During 2021, the SESAR JU worked with the US FAA – under the EU–US MoC on ATM modernisation, civil aviation research and development, and global interoperability – to define a new work structure reflecting the priorities agreed by the MoC's Executive Committee, co-chaired by the European Commission and the FAA, in March 2021. The Coordination Committee, co-chaired by the SESAR JU and the FAA, met in September to kick off the new topic and addressed theof developing new work plans across the four focus areas: the integration of new entrants, the evolution of performance-based technologies, advancing innovation in ATM and ICAO coordination.

Other bilateral contacts with international partners during 2021 were limited as a result of the pandemic situation, as mentioned above. Nevertheless, regular contacts were maintained with the Civil Aviation Authority of Singapore (CAAS) under the MoC between the SESAR JU and CAAS. This included three bilateral workshops held virtually in February and March 2021 to exchange information on the results of and lessons learned from research and demonstration activities relating to drones.

The SESAR JU participated in a limited number of international events during 2021, including the iCNS conference in April, the ICAO Drone Enable event in April and a workshop in October on the ATM Master Plan under the EU–Latin America Aviation Partnership Project led by EASA.

1.4.5.2 Stakeholder engagement

1.4.5.2.1 European Union Aviation Safety Agency

In 2021, the SESAR JU strengthened its cooperation and coordination with EASA through the signing of an interinstitutional SLA on 26 March 2021 at Executive Director level. Pursuant to this SLA, EASA is tasked with providing services to the SESAR JU within the area of ATM / air navigation services including the implementation of the SES. Under the SLA, the annual work plan for 2021 was approved in July 2021, allowing the SESAR JU to obtain support from EASA experts. This service provision is expected to be a part of the projects related to the SESAR programme with a pan-European dimension. The close cooperation with EASA also aims to bring the European Plan for Aviation Safety (EPAS), when it is updated, into alignment with the European ATM Master Plan, as these documents are the focus of the activities of EASA and the SESAR JU, respectively. The work programme for 2021 was approved at the annual Executive Director Steering Committee on 26 March 2021.

As part of the preparation of the future SESAR 3 JU activities, the SESAR JU set up dedicated bilateral meetings (10 March, 22 June and 22 October) with EASA, notably to present and discuss the content of the draft SESAR 3 JU MAWP, with a particular focus on governance, on capturing synergies with the Member States and on the future project delivery expectation, to help develop a new-generation regulatory framework and a link to standards.

1.4.5.2.2 European Defence Agency

In Europe, military aviation encompasses hundreds of military areas and dozens of military airfields. An estimated 30 % of military flights adhere to general air traffic rules, while the remainder operate as operational air traffic. Military flights are carried out for a wide variety of reasons, including as training exercises, to ensure homeland security (including sovereignty missions) and for the management of cross-border crises operations. Such missions often require immediate access to airspace, as they are frequently launched at short notice. This means that, by default, military use of airspace is immediate and unpredictable, necessitating dynamic ATM arrangements if efficient military operations are to be secured without a negative impact on the efficient overall flow of air traffic. For this reason, widespread military involvement in SESAR Solutions has been, and still is, paramount to ensure that effective military missions and airspace use can be integrated with other uses of airspace across Europe.

The SESAR JU and the EDA have been engaged in close dialogue since 2011, and this relationship continued in 2021, with dialogue focusing in particular on military matters and inputs to the SESAR R&I programme. The EDA now serves as the main interface between SESAR 2020 and SESAR JU activities, on the one hand, and military aviation and ATM, on the other, and it responsible for coordinating military views with regard to the SES and SESAR.

The cooperation under the MoC in 2021 included the creation of an EDA/SESAR JU Task Force intended to continue cooperation under SESAR 2020 and to enhance coordination when the SESAR 3 JU gets under way. This task force directly supports the EU action plan on synergies between civil, defence and space industries and ensures the complementarity between SESAR 3 and European Defence Funds respective work programmes. In the meantime, the SESAR JU and the EDA continued to harmonise their RPAS research programmes to reduce duplication and to promote dual-use solutions. During project execution, the SESAR JU participates in reviews, discussions and events relating to the EDA

RPAS activities, and the EDA reciprocates in the SESAR ER and IR projects, notably PJ13. This cooperation supports a harmonised approach to RPAS standardisation and operational integration.

1.4.5.2.3 SESAR Deployment Manager

During 2021, collaboration under the 2015 memorandum of understanding between the SESAR JU and the SDM continued, including a review of the SDM deployment programme and, in particular, the programme's annex B for alignment with the SESAR solutions catalogue.

1.4.5.2.4 Standards-making organisations

Collaboration between the SESAR JU and the standards-making organisations is part of the mitigation of risks recognised in the coordination of the ATM Master Plan.

1.4.5.2.4.1 European Organisation for Civil Aviation Equipment

The SESAR JU continued to ensure ongoing alignment between SESAR work and proposed standards developments, EUROCAE working arrangements and EUROCAE planning through its active participation in the EUROCAE Council and Technical Advisory Committee, and under the terms of the 2012 MoC between the SESAR JU and EUROCAE. This included specifically drafting parts of the EUROCAE technical work programme to ensure alignment with SESAR planning and needs, in particular to address the needs identified in the SRIA.

During 2021, SESAR deliverables were made available to several EUROCAE working groups to support the development of standards relating to several key areas of the SESAR 2020 programme, and the SESAR JU also coordinated with the equivalent special committees of the RTCA.

EUROCAE published standards in 2021 with contributions from and of direct relevance to SESAR Solutions.

1.4.5.2.4.2 European Air Traffic Management Standards Coordination Group

In 2021, the SESAR JU continued as an active participant in the European Air Traffic Management Standards Coordination Group (EASCG), with the objectives of coordinating standardisation activities, identifying their links with the R&I activities and providing a forum for discussion. In 2021, the Chair of the EASCG passed to EASA, which reflects the increasing importance of EASA in seeking to define means of compliance for regulatory activity.

During 2021, ongoing discussions were held to review and update the mechanism by which SESAR standardisation recommendations can be fed to the EASCG in a timely fashion. The SESAR standardisation roadmap remains a major input for the European ATM standardisation rolling development plan, and not only provides the reference for ATM standardisation needs in European (including SESAR-specific needs), but also serves as the basis for European input into both the process and the content of the ICAO standardisation roadmap development. The ongoing discussions seek to identify a way to provide information for inclusion in the ATM standardisation rolling development plan in a more dynamic fashion, thus enabling greater efficiency in European standardisation activities.

1.4.5.2.4.3 European Unmanned Aerial System Standards Coordination Group

In 2021, the SESAR JU continued as an active participant in the European Unmanned Aerial System Standards Coordination Group (EUSCG), with the objective of coordinating UAS-related standardisation activities and needs. As U-space becomes more mature, and the Commission has published its regulatory framework on U-space, EASA has taken over as Chair of the group. The focus of the EUSCG, supported by the SESAR JU, has been on defining means of compliance for the evolving U-space regulatory environment.

1.4.5.2.5 Civil airspace users

Civil AUs comprise a wide range of undertakings and carry out a wide spectrum of activities, including scheduled and charter flights, cargo flights, business and general flights, and rotorcraft operations.

AUs are directly integrated within the programme through four framework contracts and related specific contracts reflecting the specific interests and skills of different categories of AUs (lot 1, European scheduled airlines; lot 2, global airlines; lot 3, business aviation; and lot 4, general aviation and rotorcraft). Their expertise is recognised as key to the overall success of SESAR 2020 activities.

In 2021, despite the COVID-19 crisis, the AUs continued to support the SESAR JU in the monitoring and steering of SESAR 2020 projects, using their substantial expertise to review and comment on solution projects' deliverables, through the delivery of technical analyses, priority analyses and gap analyses. Moreover, they participated in maturity gate meetings and validation exercises and provided general technical advice. AUs' input played a key role in assuring robust assessment of the quality of SESAR Solutions and the benefits expected from their implementation. In addition to the vital project support, the AUs provided joint papers on the environment and on the performance of past engagement between the AUs and the SESAR JU, with the aim of optimising AU contribution in the future SESAR 3 JU.

1.4.5.2.6 Professional staff organisations

In 2021, the SESAR JU collaborated, under a framework contract and supporting specific contracts, with the following professional staff organisations (PSOs): the International Federation of Air Traffic Controllers' Associations (IFATCA), the European Cockpit Association, the International Federation of Air Traffic Safety Electronics Associations (IFATSEA), the European Transport Workers' Federation (ETF) and the Air Traffic Controllers European Union Coordination (ATCEUC).

In 2021, PSOs continued to provide expertise and direct support to the SESAR JU, and thereby the SESAR 2020 programme, with a large number of licensed and operational controllers, pilots and engineers of all nationalities providing relevant and cross-border operational and technical knowledge of direct relevance to the successful delivery of SESAR results and solutions. More work was conducted in 2021 than in any previous year.

In 2021, four quarterly coordination meetings were held to coordinate activities, including one that was face-to-face, with priorities defined in a work programme agreed between the SESAR JU and the PSOs in relation to ATM modernisation. Although engagement was affected by the COVID-19 crisis, the PSOs provided direct support to specific research programmes and virtual events. PSOs have co-organised webinars with the SESAR JU, and produced a joint PSO paper on environmental issues. In addition, detailed workshops have been held to address key areas of concern, such as remote towers and DAA for RPASs.

1.4.5.2.7 Airports Council International Europe

Recognising the need for further airport integration, the SESAR JU works closely with Airports Council International Europe (ACI EUROPE) to raise awareness of SESAR among its airport partners, which include airport operators beyond those represented in the the SESAR European Airports Consortium (SEAC) 2020.

In 2021, the close cooperation between ACI EUROPE and the SESAR JU continued in the form of an efficient and constructive relationship, exemplified by a first specific contract implementing the framework contract signed at the very end of 2020. Through this specific contract, the following main activities were performed.

- ACI EUROPE performed an analysis of the SESAR solutions implementation study that the association delivered to the SESAR JU at the end 2020, with the aim of refining the approach for assessing the uptake of the SESAR solutions at airports and investigating how to accelerate the deployment of the mature SESAR solutions at airports. ACI EUROPE delivered a number of conclusions and recommendations that should be used in a future follow-up study aimed at assessing the level of deployment of SESAR solutions at European airports.
- ACI EUROPE supported the SESAR JU in the following communication activities.
    - In October 2021, the SESAR JU Executive Director *ad interim* took part in a panel discussion on 'the new operational reality' at the ACI EUROPE Annual Congress and General Assembly at Geneva Airport. This was an opportunity for the SESAR JU to highlight the important role of SESAR in building a sustainable, resilient and digital system supporting European airports.
    - A SESAR JU-sponsored Digital Transformation Award was presented to Rome Fiumicino Airport at ACI EUROPE's Annual Congress and General Assembly, recognising the airport's focus on innovation and digital solutions (e.g. the airport operations centre, an innovation hub and support to start-ups). As part of the specific contract with the SESAR JU, ACI EUROPE produced a video interview of Aeroporti di Roma's CEO, offering the opportunity to a non-SESAR member airport to testify about the benefits of the programme for his organisation.
    - ACI EUROPE invited the SESAR JU to present the future Digital European Sky programme and the 'smart and sustainable solutions for greener ATM' at its Technical, Operations and Safety Committee (TOSC) meeting in November 2021.
    - ACI EUROPE and the SESAR JU signed a 2-week media partnership with EURACTIV in November 2021, which allowed SESAR to be promoted through banners, tweets and sponsored content.
    - SESAR JU communication campaigns relevant to airports were promoted on ACI EUROPE's new communication tools, including social media.
    - ACI EUROPE and the SESAR JU co-organised a webinar on efficient, connected and sustainable regional airports in December 2021.
- ACI EUROPE experts reviewed several deliverables produced by PJ04 W2 (TAM) on behalf of the SESAR JU, providing a valuable airport operational and technical view on the activities of this project.

1.4.5.2.8 National authorities

In 2021, the SESAR JU ensured the continuity of the cooperation arrangements with national supervisory authorities (NSAs) in the context of the COVID-19 pandemic. Under a bilateral MoC signed with the SESAR JU in 2017, each of the 16 NSAs attended meetings in 2021 on a quarterly basis (26 January, 6 May, 10 September and 25 November) to deal with the main areas of interest to NSAs related to the key 2021 validation and demonstration projects in the SESAR 2020 programme and U-space activities. NSAs were also asked to express their interests in SESAR solutions for initiating any dedicated meeting with involved experts. The main objective of the cooperation with NSAs remains to secure their early involvement in the definition and development activities to minimise the risks inherent to the transition between SESAR development and deployment activities.

As part of the preparation of the future SESAR 3 JU activities, the SESAR JU continuously informed the NSAs about the elaboration process of the single basic act establishing the SESAR 3 JU under the Horizon Europe programme, particularly the role of the States' Representatives Group, which is one of the main governance bodies of the new SESAR 3 JU. Given that the MoC is superseded by the

establishment of the States' Representatives Group, the SESAR JU sent a termination letter by email on 30 November 2021 to each NSA while ensuring their full agreement on this termination process.

1.4.5.2.9 Space

1.4.5.2.9.1 European Space Agency

The European ATM Master Plan clearly identifies the need for space-based positioning for navigation and communication services in support of time-based operations and TBOs, as well as for improved operations at less well-equipped airports or airports with differently equipped vehicles.

Within the context of an MoC signed between ESA and the SESAR JU in 2016, coordination between the two organisations has progressed well, particularly in relation to ESA/Inmarsat Iris activities and SESAR JU project PJ14 W2-107 on SATCOM. This activity allowed the development of a shared view on the value chain and interdependencies between the programmes. Ultimately, this coordination with ESA and the finalisation of the Iris system are key to enabling 4D operations worldwide. Informal coordination with the European Union Agency for the Space Programme continued during 2021. This included in-depth coordination in the context of the update of the European ATM Master Plan, in particular to highlight the role of EGNOS and Galileo in the future multifrequency, multiconstellation GNSS.

Additionally, the coordinated development of a GNSS GBAS development and deployment plan was started in 2021.

1.4.5.2.10 Clean Sky 2 Joint Undertaking

In 2021, cooperative arrangements with the Clean Sky 2 Joint Undertaking ([35]) continued under the MoC signed in December 2015. Cooperation in 2021 focused on identifying synergies and complementarities in the two organisations' programmes.

1.4.5.2.11 Communications, Navigation and Surveillance Advisory Group

The high-level group on SES implementation agreed on principles and provided guidelines for an optimal CNS infrastructure implementation. It subsequently established a CNS Advisory Group to develop recommendations to ensure the best possible organisation, management and implementation of a CNS infrastructure based on these principles. The approach has been to further develop the conclusions of the CNS symposium organised by EUROCONTROL in October 2018 by identifying key issues and assessing their root causes, the interdependencies among them and their consequences.

The CNS Advisory Group started its work in June 2020 under the chairmanship of the European Commission. SESAR JU subject matter experts contributed to this CNS Advisory Group by bringing an R&I perspective. The CNS Advisory Group was further enlarged in July 2021 with representatives from CANSO, the IATA/AUs, the ACI, the Expert Group of Human Dimension chair team and the the Industry Consultation Body chair team.

The CNS Advisory Group has developed recommendations aimed at achieving more comprehensive, reliable and accurate planning for CNS implementation; proposing incentives for voluntary implementation complemented by smart(er) regulations; improving management and governance; and considering human dimension aspects. The report includes an appendix that covers actions that

([35]) Council Regulation (EU) No 558/2014 of 6 May 2014 establishing the Clean Sky 2 Joint Undertaking (OJ L 169, 7.6.2014, p. 77).

can be taken to move forwards in terms of the proposed recommendations. The implementation of the action plan will require the collective effort and buy-in of civil stakeholders and states, including military and other public organisations, and therefore will be consolidated through consultation with all of them. The action plan should address the implications for all stakeholders. The progress was presented to the SES high-level group in 2021 and the full document is currently scheduled to be presented around May 2022.

1.5 External evaluations

The SESAR JU was subject to two evaluations in 2017. One concerned the closure of the SESAR 1 programme (the final evaluation of SESAR 1: 2007–2016[36]), while the second focused on ongoing research activities under the SESAR 2020 programme (an interim evaluation of SESAR 2020: 2014–2020[37])).

The SESAR JU management considers that the action plan related to both evaluations has been implemented except for one recommendation[38], which has been put on hold, as it is subject to the next multiannual financial framework.

In 2021, the SESAR JU was not subject to an external evaluation.

1.6 Dissemination and information about project results

In 2021, a series of actions were implemented aimed at raising awareness among the beneficiaries about the importance of dissemination and information of the projects' results. The activities implemented were tailored to the specific situation of the projects, depending on the different projects' implementation stages.

In 2021, the SESAR JU appointed a dissemination, exploitation and communication correspondent within the Grant Management Team.

In this capacity, the correspondent delivered a training session on dissemination and exploitation for grant managers and programme managers at the JU. She also attended meetings of the JU's Communication Coordination Group (a coordination group made up of communication experts among the JU members) to promote the need for disseminating the projects' results.

Additionally, she provided feedback to colleagues in the JU team on specific requests related to dissemination and exploitation.

Projects-specific information is available in Section I.4, as well as in the separate annex in the KPIs section.

([36]) The full report of the final evaluation of the SESAR Joint Undertaking (2014-2016) operating under the SESAR 1 Programme (FP7) is available on the following website: https://op.europa.eu/en/publication-detail/-/publication/038997f2-ae38-11e7-837e-01aa75ed71a1/language-en/format-PDF/source-43224412

([37]) The full report of the interim evaluation of the SESAR Joint Undertaking (2014-2016) operating under Horizon 2020 is available on the following website: https://op.europa.eu/en/publication-detail/-/publication/5590dcea-ae3b-11e7-837e-01aa75ed71a1/language-en/format-PDF/source-43224356

([38]) Recommendation 5 "*Take steps to further close the industrialisation gap*" is subject to validation at political level and was therefore put on hold.

1.7 Operational budget execution

Figure 10 shows the commitments budget allocation by area of operation.

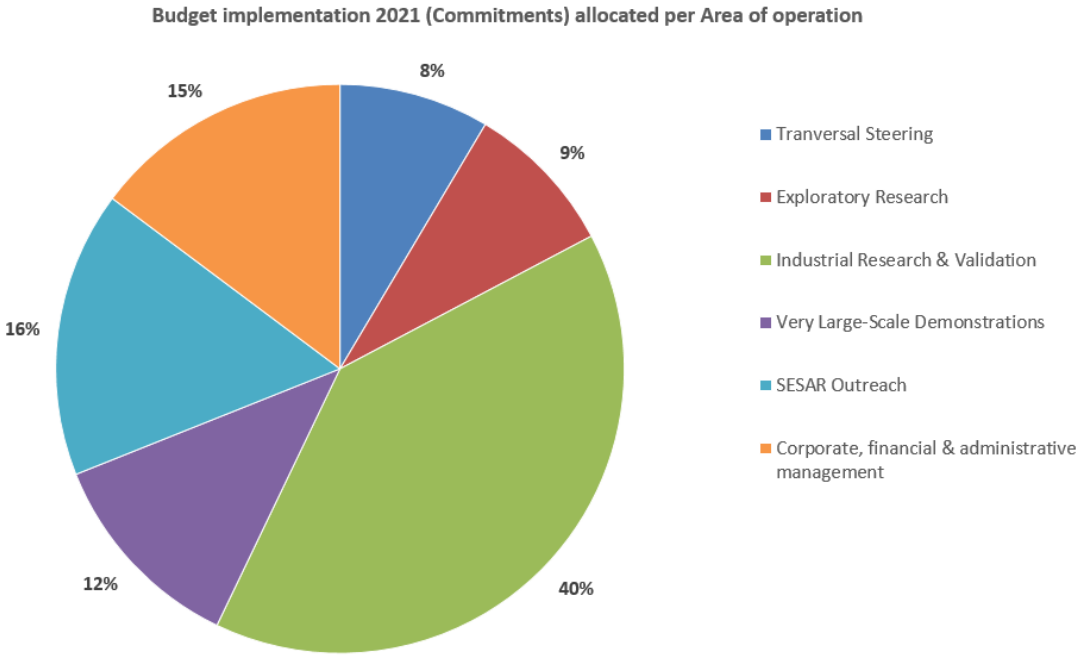


Figure 10: 2021 commitments budget allocation by area of operation

Figure 11 shows the payments budget allocation by area of operation (total).

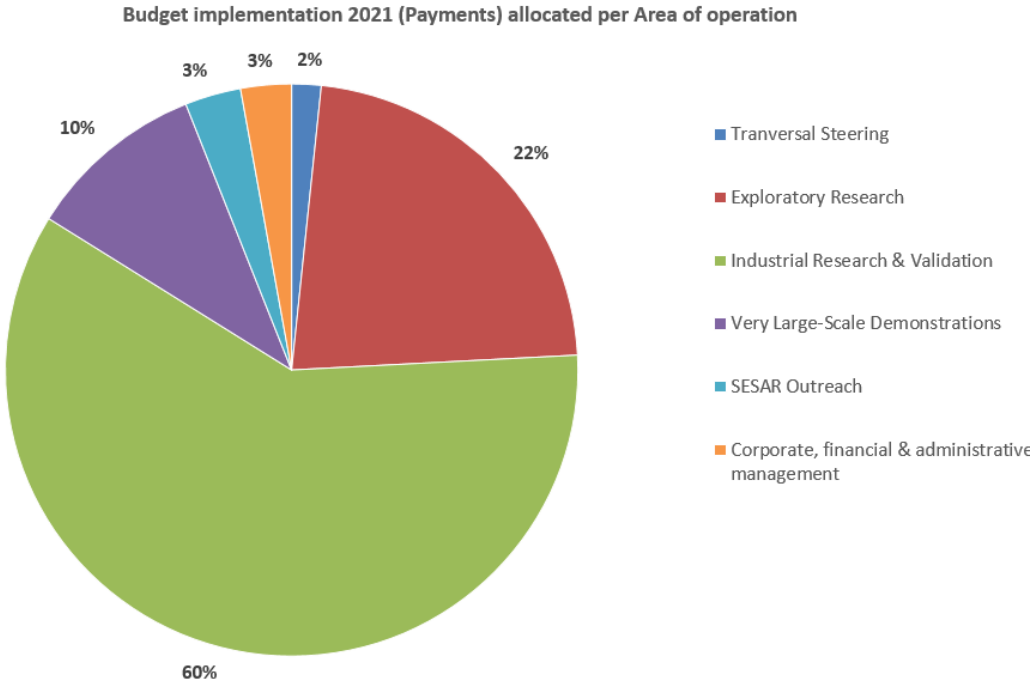


Figure 11: 2021 payments budget allocation by area of operation

1.8 In-kind contributions for the SESAR 2020 programme

During 2021, the in-kind contributions of SESAR JU members other than the EU were assessed for the fourth reporting period of wave 1 projects and the first reporting period of wave 2 projects (covering activities performed in 2020). The actual in-kind contributions validated in 2021 amounted to EUR 75 796 203. For reporting periods 1, 2 and 3, a total of EUR 347 213 084 has been validated (Table 5).

Table 5: In-kind contributions for SESAR 2020

MEMBERS	Total Net IKOP EUR (Total for SESAR2020)	Year 2018 Reporting period 1 Net in-kind contribution validated by ADB	Year 2019 Reporting period 2 Net in-kind contribution validated by ADB	Year 2020 Reporting period 3 Net in-kind contribution validated by ADB	Year 2021 Reporting period 4 Net in-kind contribution validated by ADB	Year 2021 Reporting period 4 Net in-kind contribution to be validated by ADB	Total Net in-kind contribution validated/to be validated by ADB	% Total for SESAR2020	Year 2022 Reporting period 5 Estimated reported in January 2022	Total Total Net in-kind contribution validated/to be validated by ADB	% Total for SESAR2020
AIRBUS	25.093.735	8.456.750	6.745.919	4.488.737	2.208.405		21.899.810	87,27%	3.391.292	25.291.102	100,79%
AT-ONE Consortium	11.867.806	2.182.055	2.462.078	2.438.023	1.045.080		8.127.236	68,48%	2.800.261	10.927.497	92,08%
B4 Consortium	1.985.379	191.414	624.579	446.221	159.251		1.421.466	71,60%	262.508	1.683.973	84,82%
COOPANS Consortium	8.676.061	1.488.668	1.851.508	710.548	543.205		4.593.929	52,95%	957.483	5.551.412	63,99%
DASSAULT Aviation	1.806.681	196.712	295.271	331.679	129.997		953.658	52,79%	348.632	1.302.290	72,08%
DFS	7.810.987	2.787.277	3.066.617	2.100.348	1.123.452		9.077.693	116,22%	1.228.287	10.305.980	131,94%
DSNA	9.190.202	2.010.870	2.026.127	1.528.476	984.893		6.550.366	71,28%	1.159.694	7.710.060	83,89%
ENAIRE	15.617.352	2.648.178	2.501.744	2.352.972	2.095.613		9.598.506	61,46%	1.987.105	11.585.612	74,18%
ENAV	7.499.310	1.236.711	1.479.624	1.351.172	863.669	81.925	5.013.101	66,85%	1.036.649	6.049.750	80,67%
FREQUENTIS Consortium	6.410.132	808.991	1.080.775	1.221.359	564.690		3.675.815	57,34%	921.797	4.597.612	71,72%
HONEYWELL AEROSPACE	14.546.257	3.021.431	3.284.206	2.019.526	1.210.542		9.535.705	65,55%	1.829.712	11.365.417	78,13%
INDRA	19.878.000	4.066.800	5.668.406	2.924.046	2.145.507		14.804.760	74,48%	3.344.776	18.149.536	91,30%
LEONARDO	45.835.829	6.671.150	8.608.064	5.709.422	5.834.084		26.822.720	58,52%	6.689.524	33.512.244	73,11%
NATMIG Consortium	9.960.423	2.050.535	1.990.565	1.977.098	1.283.759		7.301.958	73,31%	1.731.466	9.033.423	90,69%
NATS	8.708.327	1.405.703	1.829.382	1.413.114	1.606.269		6.254.468	71,82%	1.847.431	8.101.899	93,04%
SEAC2020 Consortium	2.351.979	0	666.154	308.691	236.082	36.403	1.247.330	53,03%	254.443	1.501.773	63,85%
SKYGUIDE	1.373.305	263.677	374.675	278.669	107.637		1.024.657	74,61%	447.514	1.472.171	107,20%
THALES AVS	32.713.185	8.052.589	7.434.047	8.029.077	4.929.767		28.445.480	86,95%	3.853.638	32.299.118	98,73%
THALES LAS	48.700.000	6.695.308	8.763.602	6.345.208	4.197.611	201.066	26.202.795	53,80%	10.320.791	36.523.586	75,00%
TOTAL	**280.024.950**	**54.234.818**	**60.753.342**	**45.974.388**	**31.269.511**	**319.394,16**	**192.551.454**	**68,76%**	**44.413.004**	**236.964.458**	**84,62%**
ECTL	433.418.444	59.602.725	66.067.916	60.579.895	44.526.692		230.777.228	53,25%	45.873.150	276.650.379	63,83%
Grand Total	713.443.394	113.837.543	126.821.258	106.554.283	75.796.203	319.394	423.328.682	59,34%	90.286.154	513.614.836	71,99%

The estimates reported by all members in January 2022 (for costs incurred in 2021) amount to EUR 90 286 154 and the net in-kind still to be validated EUR 319 394, which brings total net in-kind contributions to EUR 513 614 836 (71.99 % of the net in-kind contributions laid down in the membership agreement).

2 Implementation of the annual work programme for 2021 (support to operations)

In 2021, the SESAR JU met all of its objectives related to the communication strategy and activities, as well as to effective financial, administrative and corporate management, as set out in Section III of the SPD for 2021–2023. This includes the following achievements and results.

- Promoting SESAR JU activities and results through publications, workshops and events. Dissemination activities were carried out in accordance with the plan. Owing to the COVID-19 pandemic, most of the events were held virtually.
- Monitoring the efficiency and effectiveness of the SESAR JU's legal activities. Activities were carried out in accordance with the plan agreed with the requestor and with the SPD for 2021–2023 procurement plan.
- Ensuring full compliance with programming and reporting requirements. SPDs were developed and submitted on time, as per the requirements. Preparations for the biannual work programme of the SESAR 3 JU were initiated in July 2021. The CAAR for 2020 and the report on the implementation of the delegation agreements on U-space and geofencing were adopted and submitted on time.
- In 2021, the SESAR JU received no 'critical' observations and no 'very important' recommendations from the auditors. Also, no files were sent to the European Anti-Fraud Office (OLAF) for investigation.
- Monitoring the efficiency and effectiveness of budget and finance activties: (1) the budget request for 2022 was submitted to the European Commission before 31 January 2021 (date of actual submission: 25 January 2021); (2) the percentage of SESAR 2020 balancing payments executed in a timely manner was 95.47 %; (3) the 2020 annual accounts were completed and published within the regulatory deadlines before 1 July 2021 (transmitted to the budgetary authority on 30 June 2021); and (4) support was provided for the European Court of Auditors (ECA) audit and in the provision of relevant documentation leading to an unqualified opinion on the 2020 accounts.
- Monitoring the efficiency and effectiveness of the SESAR JU's procurement activities. Activities were carried out in accordance with the plan agreed with the requestor and with the SPD for 2021–2023 procurement plan.
- Delivering infrastructure services to enable teams and the SESAR JU to operate smoothly. Services were delivered in line with the plans. Business continuity measures were implemented, and infrastructure services proved to be effective in this regard.
- Monitoring the efficiency and effectiveness of human resources management. The elements that were monitored were: (1) effective staffing management (the maximum turnover rate was 7.5 % and the minimum occupancy rate was 92.5 %); (2) the implementation of staff appraisals and reclassification exercises (100 %) in line with the EU staff regulation and the SESAR 3 JU implementing rules; and (3) the implementation of, or opt-out from, Commission implementing decisions and models (100 % for 2021).

2.1 Communication, dissemination and exploitation

2.1.1 Strategy

In 2021, the SESAR JU carried out a number of strategic activities in preparation for the launch of the new joint undertaking. These included:

- reviewing the 2015–2020 communications strategy, building on the results of a survey of subscribers to SESAR JU communications channels;
- drafting a new strategy, covering the key objectives, audiences and messages of the new partnership, and sound boarding the strategy among staff and selected members of the SESAR JU Communications Coordination Group;
- designing visual branding for the new joint undertaking and developing graphical elements and supporting guidance material, for approval by the SESAR 3 JU Governing Board.

2.1.2 Events and conferences

Over the course of 2021, the SESAR JU events schedule continued to be affected by the COVID-19 social distancing restrictions, with the result that the majority of events in which the SESAR JU had intended to participate were cancelled or postponed until 2022. Despite these challenges, the SESAR JU maintained visibility by providing a speaker at over 40 online events and/or conferences (Figure 12).

Figure 12: SESAR JU events in 2021

2.1.2.1 SESAR Digital Academy webinar series

In order to maximise visibility and outreach in 2021, the SESAR JU organised a series of technical webinars aiming to provide an overview of SESAR 2020 achievements and provide a flavour of concrete benefits that ATM modernisation is starting to bring to the entire aviation ecosystem. The webinars were intended to explore what still needs to be done and, in particular, how technology can bring about fundamental changes to the way we manage air traffic in European airspace.

Over the course of the year, five webinars were held under the banner of the SESAR Digital Academy (Table 6). A number of key stakeholders and partners were invited to present their success stories, and

the webinars were moderated by SESAR JU ATM experts. The webinars attracted, on average, over 550 participants, amounting to a global audience of around 3 000 participants throughout the course of the year.

The webinars featured content from SESAR projects and related to the ATM context. Each webinar included three or four technical presentations followed by a moderated Q&A session; in addition, effort was made to facilitate interaction with the audience by providing a fully transparent live chat facility throughout each webinar; all questions and answers were made visible to the live audience. The webinar format made the content of the SESAR programme accessible to the European public in a way that had never been possible before. After each webinar, all material (presentations, a webinar replay link and full live Q&A file) was made available online, constituting a permanent and invaluable educational online resource library for the future.

Table 6: Webinars in 2021 and playback links

Title	Date	More information	Replay
Smarter, safer and more efficient arrivals (Part 2)	21 October	More info	Replay
Smarter, safer and more efficient arrivals	28 September	More info	Replay
Automated speech recognition for air traffic control	11 May	More info	Replay
Innovation in airspace utilisation	29 April	More info	Replay
ATM cybersecurity – The industry view	25 February	More info	Replay

In addition to the SESAR Digital Academy webinars, the SESAR JU joined forces with ACI EUROPE on 3 December 2021 to organise a webinar aimed at exploring how regional airports are working to deliver smart, efficient and sustainable operations through collaborative management, connectedness and technological innovation. As part of the webinar, the SESAR AAL2 demonstration was presented, providing concrete examples of how SESAR solutions are improving accessibility of regional aerodromes. More information and the webinar playback can be found on the SESAR JU website.

2.1.2.2 L-band digital aeronautical communication system webinar series

LDACS is a modern and advanced air–ground secured communication technology that also has navigation and surveillance capabilities.

LDACS is now reaching sufficient technical and standardisation maturity and is considered a strong candidate to enhance the current and future mobile data link applications as part of the FCI.

In order to support any potential upcoming decisions on large-scale demonstration and deployment, a series of three webinars were organised by the SESAR JU and EUROCONTROL, together with panels of experts from the ICAO, the IATA, the FAA, industry, ANSPs, AUs and communication service providers (Table 7).

The SESAR JU hosted these webinars on behalf of the Joint CNS Stakeholder Platform.

Table 7: Webinars held by the SESAR JU in 2021

Title	Date	More information	Replay
LDACS deployment and transition scenario	1 July	More info	Replay
Technical details and capabilities of LDACS	2 June	More info	Replay
Introduction to LDACS	23 April	More info	Replay
ATM cybersecurity – The industry view	25 February	More info	Replay

2.1.2.3 SESAR Joint Undertaking internal meeting

On 27 April 2021, the SESAR JU organised its annual internal meeting with representatives from its core membership and key stakeholders in order to provide an update on the status of the programme and to highlight ATM modernisation priorities both within Europe and beyond. Speakers included:

- Henrik Hololei, Director General, Directorate-General for Mobility and Transport,
- Stephen Creamer, Director, Air Navigation Bureau,
- Eamonn Brennan, Director General, EUROCONTROL,
- Filip Cornelis, Director Aviation, Directorate-General for Mobility and Transport,
- Florian Guillermet, Executive Director, SESAR JU.

At a time when there is much discussion about the future of aviation and ATM modernisation, the event was an opportunity for the SESAR JU community to put their questions to the panel and hear more on the progress of SESAR 2020 and the vision for the future of the programme.

The highlight of the event was a panel discussion, led by a distinguished journalist, Jacki Davis – who took questions from the audience both in advance and during the event. The key message of the event was that the COVID-19 pandemic had highlighted the need for a sustainable and smart recovery, as well as the need to strengthen the resilience of the sector.

The event welcomed 250 participants, and those that joined appreciated the opportunity to participate in virtual networking at the end of the event – giving the SESAR JU community a much-needed chance to reconnect after such a long period of social distancing.

2.1.2.4 SESAR Digital European Sky Awards

On 17 June, the SESAR JU announced the winners of the 2021 Digital European Sky Awards, celebrating the best of R&I in ATM in Europe.

The five winning projects were selected from a shortlist, following rigorous evaluation by a distinguished jury of SESAR JU members and partners and a public vote. In total, 37 projects were nominated across five award categories:

1. ER (16 contributions)
2. IR (10 contributions)
3. demonstrations (four contributions)
4. U-space (five contributions)
5. sustainable ATM (four contributions).

The projects awarded are emblematic of the work under way to deliver smarter and more sustainable air transport, across all three strands of research that make up the SESAR innovation pipeline.

The winners were announced during an awards ceremony, attended by over 300 participants and featuring some opening words of support by European Commissioner Adina-Ioana Vălean.

The list of winners and the full playback of the ceremony can be found here:

https://www.sesarju.eu/news/winners-sesar-ju-digital-sky-awards-announced

2.1.2.5 Engage SESAR Summer School in 2021

The third Engage SESAR Summer School was held virtually, with almost 100 participants from 20 countries taking part over 4 days, from 30 August to 2 September. In comparison with previous Summer Schools, at this one, more time was devoted to PhDs presenting their near-final work and obtaining targeted feedback from the industry, to help give an overview of some perspectives that are open to them at the end of their studies.

The Summer School had a focus on Engage PhDs; however, the programme proved to be attractive to other PhD/MSc students and young researchers, as well as to a number of industry participants. The event achieved the objective of establishing a forum for the exchange of ideas between industry and academia, thereby fulfilling an educational purpose as well as supporting the uptake of academic research by the ATM industry. The lecture materials have been made publicly available on the Engage website and constitute a valuable educational resource for the future.

More about the Engage project can be found in Section I.4.1.1 above.

2.1.2.6 SESAR Innovation Days, 7–10 December (virtual)

The SESAR Innovation Days are the main vehicle for the SESAR JU to share progress and disseminate the results of its ER programme. Unlike other scientific events in ATM research, SESAR Innovation Days focus explicitly on long-term and innovative research.

The 11th SESAR Innovation Days took place in a virtual capacity from 7 to 9 December.

As in other years, scientific papers and presentations shaped the 2021 event. These papers were selected from the responses to an open call for contributions published in May 2021 on the SESAR Innovation Days website, and promoted through emails, SESAR newsletters and the Engage website. The selection process was managed by the Engage network, which was selected as part of the third SESAR 2020 ER call in order to inspire new researchers and to help facilitate the transfer of results of fundamental and applied research to industrial research.

Contributions were reviewed by the Programme Committee, including members of the SESAR Scientific Committee and the SESAR JU. In total, 37 papers (out of 77 contributions, an acceptance rate of 49 %) and 30 posters were selected, which is in line with the previous SESAR Innovation Days. Attendees, numbering 758 in total, came mainly from European research and development centres and universities, but also included a number of industry representatives. An average of 200 participants joined the event at any one time (with a peak of 293), with participation gradually decreasing over the course of the event.

In addition, 771 people downloaded and used the event app, of which 659 were active app users. Keynote speeches, plenary talks and discussion panels took place in plenary sessions, while technical sessions were conducted in parallel.

All relevant information including the call for papers, submission instructions and, at a later stage, programme and conference registration were available via the SESAR Innovation Days website. All posters and papers are available to download from the website, together with the presentations and virtual posters. As reported above, a dedicated smartphone app was also available. This included relevant information and allowed users to comment and engage in dialogue, and this years was the primary way for attendees to contact each other.

During the closing remarks, the SESAR JU announced the 2022 SESAR Innovation Days, which, if the COVID-19 pandemic allows, will be held in Budapest.

All content was recorded, ensuring that the presented material has a longer ‘shelf life’ and creating valuable online content for the SESAR Digital Academy. The material can be found on the SESAR JU website.

More information on the content of the SESAR Innovation Days and the benefits they bring is provided in Section I.4.2.3.1 above.

2.1.3 Publications

A number of publications were published throughout the year (Table 8) and were promoted through online channels and at key events (see Section II.1.2).

Table 8: Key publications of the SESAR JU in 2021

SESAR Innovation Pipeline: Air traffic management research and innovation 2020 highlights

This brochure provides highlights of some of the SESAR R&D activities that took place over the course of 2020. The brochure features updates from each strand of the programme: ER, IR and VLDs. Together, these strands form an innovation pipeline through which ideas are transformed into concrete solutions.

View publication

SESAR Solutions Catalogue 2021

The publication contains 101 delivered solutions (reaching the required level of maturity for industrialisation) addressing key areas of the ATM value chain. The catalogue also presents details of the ongoing R&I in 80 candidate solutions in SESAR 2020, and progress towards the vision of the digital European sky. Finally, the publication gives a flavour of what is on the horizon thanks to promising innovations under way in all three strands of research (ER, IR and VLDs).

View publication

U-space Research and Innovation Portfolio

The brochure presents an overview of the current portfolio of projects addressing the requirements for UAM and the safe integration of drones into Europe's airspace (U-space), across the SESAR R&I programme.

View publication

Delivering the Digital European Sky

The brochure presents the rationale for the SESAR 3 JU and details its mission, scope of activities and expected benefits. The brochure also gives details of the partnership's governance structure, funding and modus operandi.

View publication

2.1.4 Press

In 2021, the SESAR JU continued its outreach to trade press and member/partner media channels, with more than 18 feature articles and interviews published in a range of magazines and online media:

- *The Parliament Magazine*,
- the French Civil Aviation Authority (DGAC) *Aviation Civile* magazine,
- the ATC Network on 11 May,
- unmannedairspace.info,
- *AIR International*,
- *Aerospace Tech Review*
- *Aerospace Testing International*
- the *EASN Newsletter* on 1 January,
- the Council of European Aerospace Societies (CEAS) *Aerospace Europe Bulletin*.

The SESAR JU website provides an overview of 2021 coverage.

Through its contract with ACI EUROPE, the SESAR JU also conducted a media campaign in collaboration with EURACTIV, which saw the inclusion of banners, tweets and SESAR JU branding in EURACTIV communications cannels (i.e. its website, social media and newsletter). The media partnership resulted in increased traffic to the SESAR JU website.

2.1.5 Online communications

2.1.5.1 Website and e-news

The SESAR JU revamped its website in preparation for the launch of the new partnership, applying the new visual branding, introducing new content and simplifying the navigation. Among the most popular content on the website were the U-space and drone developments, the library, the SESAR Innovation Days content and the vacancy notices.

Monthly e-news was sent to nearly 7 500 external contacts (all compliant with the general data protection regulation). In addition, over 56 dedicated event mailshots and press releases were distributed, attracting further traffic to the SESAR JU website. An analysis shows a positive open rate of 33.81 % compared with the transportation industry average open rate (20.44 %).

2.1.5.2 Social media

In 2021, SESAR JU social media communication achieved positive results in terms of performance. Starting with its activities, the SESAR JU published 995 posts across its social media channels (Figure 13), compared with 430 in 2020, representing a growth rate of more than 130 %. Owing to an increase in owner activity and online community growth, the engagement rate on Twitter doubled compared with that of LinkedIn and YouTube. In terms of enlarging the online community, the SESAR JU saw an increase in the number of followers across all channels, especially on LinkedIn (Figure 14). The improved performance can be explained by a series of scheduled promotion campaigns, which helped increase the visibility of the SESAR JU across the channels on which it is active.

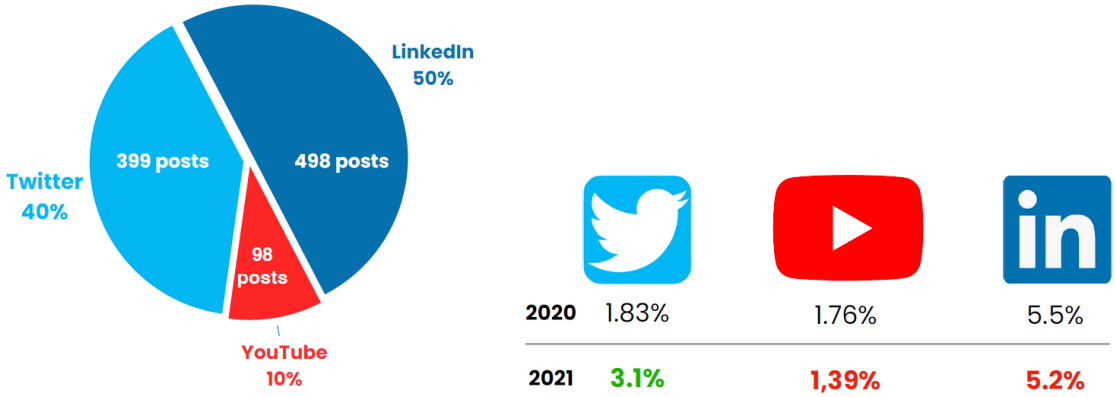


Figure 13: The SESAR JU on social media

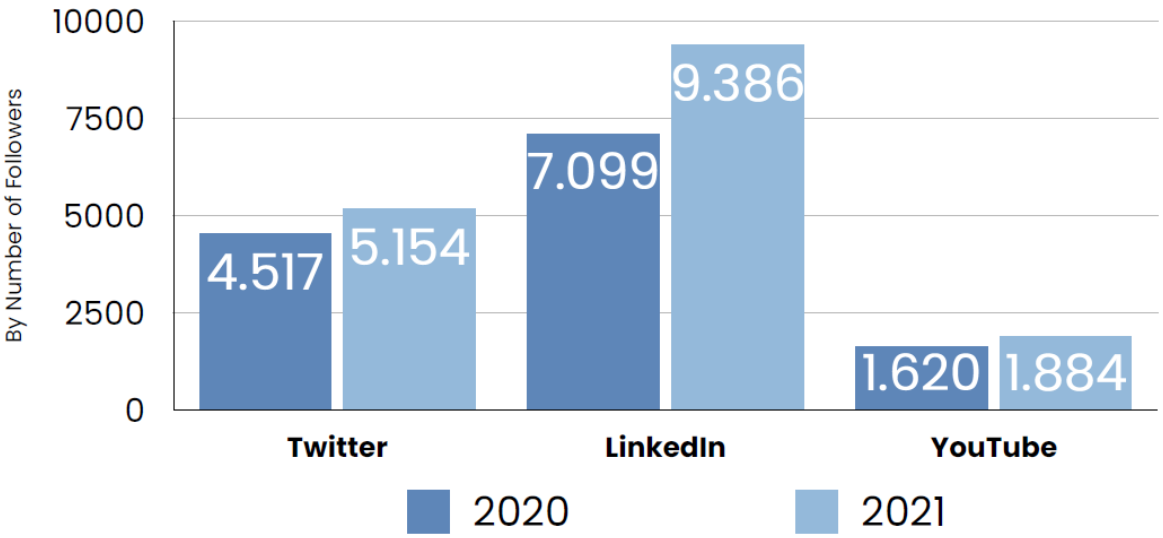


Figure 14: The SESAR JU's online communities by social media platform

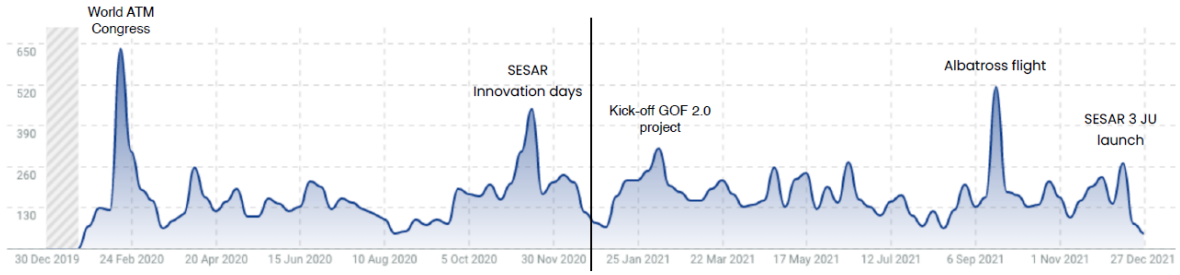


Figure 15: The SESAR JU's peak engagement

The engagement rate and views on both Twitter and LinkedIn peaked at a number of communications milestones, including the SESAR Innovation Days and a number of demonstration flight trials, illustrating the importance of strong collaboration on communications between the SESAR JU and its projects (Figure 15).

2.2 Legal and financial framework

The SESAR JU is a joint undertaking within the meaning of Article 187 of the Treaty on the Functioning of the European Union, set up by Council Regulation (EC) No 219/2007 of 27 February 2007 (OJ L 64, 2.3.2007, p. 1) on the establishment of a joint undertaking to develop the new generation European air traffic management system (SESAR), as amended by Council Regulation (EC) No 1361/2008 of 16 December 2008 (OJ L 352, 31.12.2008, p. 12) and by Council Regulation (EU) No 721/2014 of 16 June 2014 (OJ L 192, 1.7.2014, p. 1).

In line with Article 112(2) of Commission Delegated Regulation 2019/715 on the framework financial regulation for the bodies set up under the Treaty on the Functioning of the European Union and the Euratom Treaty and referred to in Article 70 of Regulation (EU, Euratom) 2018/1046 of the European Parliament and of the Council, the SESAR JU revised its financial rules. The revision process was concluded in October 2019 by the adoption of the new financial rules by the Administrative Board (ADB(D)21-2019).

In 2019, the European Commission launched activities to determine options for an integrated ATM partnership (SESAR 3) in the next multiannual financial framework (2021–2027). The European Commission published a legislative proposal in February 2021, which led to a new Council regulation adopted on 19 November 2021, which entered into force on 30 November 2021. In accordance with Article 174(9) of this regulation, the SESAR 3 JU became 'the legal and universal successor in respect of all contracts, including employment contracts and grant agreements, liabilities and acquired property of the SESAR JU …, which shall replace and succeed'.

In line with Article 60(2) of the model financial regulation for public–private partnership bodies falling under Article 71 of the financial regulation of 2018, the SESAR 3 JU adopted its financial rules during the first meeting of the Governing Board on 14 December 2021 (GB(D)01-2021).

2.2.1 Legal support to operations

In 2021, the SESAR JU paid particular attention to:

- the regularity and legality of all of the SESAR JU's binding agreements, contracts, H2020 ([39]) and non-H2020 grants ([40]) related amendments, decisions, processes and measures;
- respecting the partnership principles agreed with SESAR JU members (in the membership agreement) and their development (including the signing and management of two secondment agreements);
- respecting the agreements concluded with the SESAR JU's founding members (delegation agreements with the Commission, the SESAR JU–EUROCONTROL agreement, SLAs, etc.).

Of particular relevance with regard to legal aspects in 2021 were also the following elements:

- the development of the single basic act establishing joint undertakings under Horizon Europe, related documents (including the JU-specific Horizon Europe model grant agreement, templates, and guidelines proposed by the Directorate-General for Research and Innovation and the Directorate-General for Mobility and Transport) and information technology (IT) systems;
- preparation and transversal coordination of the transition towards the SESAR 3 programme;
- clarification of the impacts of the withdrawal of the United Kingdom from the EU and of the EU/United Kingdom Trade and Cooperation Agreement on the governance of the SESAR JU and on its procurements, grants and membership;
- the financial closure of SESAR 1 with the early repayment of the excess financial contributions received from SESAR JU members under SESAR 1 (see Section II.5.1);
- the management of the impacts of the COVID-19 crisis on ongoing programme actions;
- support to the European Commission during the preparation of the legislative act setting a new joint undertaking to repeal and replace the current SESAR JU under the Horizon Europe programme (the SESAR 3 JU) and from 2021 to 2031.

In compliance with the applicable rules ([41]), legal expertise was provided in the management of five requests ([42]) for access to documents made by the public.

As a result of the case-by-case basis analysis of each request received, the SESAR JU granted full access on three occasions, while partial access was granted once and access to documents was refused once.

([39]) Mainly for the topics related to *force majeure*, the Early Detection and Exclusion System database, consortium composition changes and intellectual property rights.
([40]) Mainly relating to U-space, with eight amendments to CEF grants.
([41]) Article 15(3) of the Treaty on the Functioning of the European Union; Article 42 of the Charter of Fundamental Rights of the EU; Regulation (EC) No 1049/2001 of the European Parliament and the Council of 30 May 2001 regarding public access to European Parliament, Council and Commission documents; and Article 34 of Council Regulation (EU) 2021/2085 of 19 November 2021 establishing the joint undertakings under Horizon Europe. These practical arrangements for public access to documents of the SESAR 3 JU are governed by Decision ADB(D)12-011 of the Administrative Board of the SESAR JU concerning the transparency and public access to the documents of the JU, and by further internal rules of the SESAR JU (Executive Director Decision SJU/ED/683 and its amendments) transferred to the SESAR 3 JU.
([42]) Article 17 of Regulation (EC) No 1049/2001 sets forth that 'each institution shall publish annually a report for the preceding year including the number of cases in which the institution refused to grant access to documents, the reasons for such refusals and the number of sensitive documents not recorded in the register'.

Partial access was justified by invoking Article 4(1)(b) ([43]) of Regulation (EC) No 1049/2001 regarding public access to European Parliament, Council and Commission documents ([44]).

One request for access to a document was refused based on Article 4(2) ([45]) and 4(1)(a) ([46]) of Regulation (EC) No 1049/2001.

So far, no sensitive documents have been recorded in the SESAR JU documents register.

2.3 Data protection

In addition to consolidating several initiatives in the area of data protection and continuing its regular work in the field, the SESAR JU overcame the following major challenges during 2021:

- continuous management of the COVID-19 pandemic;
- extensive use of new technologies and guidance for controllers/colleagues on the follow-up of recommendation from the European Data Protection Supervisor (EDPS) in the field of international data transfers;
- the transition to SESAR 3 and strong cooperation with EUROCONTROL;
- the Internal Audit Service (IAS) audit on HR management and ethics in the SESAR JU.

The COVID-19 pandemic raised the need for extensive advice on the use and design of new processes in strict compliance with the guidelines of the EDPS and the European Commission on topics such as returning to work at premises, social distancing, contact tracing, temperature, and COVID-19 certificate checks for access to premises or events organised by the SESAR JU.

As required by the EDPS following the 'Schrems II' judgement on the need to conduct data protection (or transfer) impact assessments (DPIAs) for any new transfer to the United States, the SESAR JU conducted its first DPIA on the use of the Zoom app in strict cooperation with the communications and the information and communication technology (ICT) teams. The data protection officer provided extensive advise on data transfers on different forums from staff to quality ICT (QICT).

The transition to SESAR 3 raised the need to update the current system of records and information contained online / in the register, to define new records for new governing structures, and to develop data protection clauses regulating member's relationship with the SESAR 3 JU. In addition, a draft text of joint controllership was reached in close cooperation with EUROCONTROL's data protection officer aimed at setting up the rules for cooperation with a view to setting up a future common back office.

([43]) Access has to be refused if its disclosure would undermine the protection of privacy and the integrity of the individual, in particular in accordance with EU legislation regarding the protection of personal data

([44]) Regulation (EC) No 1049/2001 of the European Parliament and of the Council of 30 May 2001 regarding public access to European Parliament, Council and Commission documents (OJ L 145, 31.5.2001, p. 43–48).

([45]) Access has to be refused if its disclosure would undermine the protection of commercial interests of a natural or legal person, including intellectual property.

([46]) Access has to be refused if its disclosure would undermine the protection of the public interest as regards public security, defence and military matters, international relations and the financial, monetary or economic policy of the community of a Member State. Accordingly, the disclosure of the requested documents is prevented by the exception to the right of access laid down in Article 4(1)(a); the application of this article was confirmed by the European Commission, which consulted the SESAR JU on this matter.

For the purpose of readiness for the IAS audit, the full set of records on HR and audits ([47]) was reviewed. The data protection officer was interviewed and provided theses and information on documented data breaches and information on data protection tailor-made training. As a result, no final recommendations were made in this area.

In its role as granting authority, the SESAR 3 JU proposes a predefined template for the submission of deliverables. This template included an authorship table with the option to be nominative (name and surname of the author(s)) or anonymised (only the name of the participant to the consortium). The authors' consent should be collected in case of a nominative table, as mentioned in the relevant privacy statement.

As per the applicable data protection legislation, the beneficiary/consortium is the Controller for the processing of personal data within the project and the one deciding on this matter. The DMSC Members decided that the authoring table would only contain the names of the participating entities within any published Wave 2 and Wave 3 S2020 Deliverables.

In parallel, the SESAR JU continued to demonstrate its compliance with the data protection regulation ([48]) on several levels.

- The data protection central register was populated with approximately a further 20 records in the areas of communication, grants and procurement, facilities, and governance; 14 existing records were updated in the field of HR. In addition, common records with EUROCONTROL were initiated.
- Contributions were made to and comments were made on the SESAR JU thematic policies on ICT.
- On specific SESAR JU data protection policies, the rules on restrictions of access to rights from data subjects were reviewed in the light of SESAR 3, and the drafting of the implementing rules of the data protection officer is ongoing.
- With the aim of creating a data protection culture, thematic emails were sent to staff on data protection.
- The EDPS was notified of a data breach, and there was strong cooperation with ICT on security matters and internal security / ICT policies with positive feedback from the EDPS.
- Extensive advice was produced on the use of new software (international transfers), publications, consent under different legal bases, the interpretation of contracts, data breaches and COVID-19.
- The preparation and performance of a DPIA was coordinated.

([47]) These records included the recruitment and selection of staff, personal files, probationary periods, reclassification, leave and working time, health data, SYSPER, learning databases, declarations of interest, harassment, whistleblowing and anti-fraud.

([48]) Regulation (EU) No 2018/1725 of the European Parliament and of the Council of 23 October 2018 on the protection of natural persons with regard to the processing of personal data by the Union institutions, bodies, offices and agencies and on the free movement of such data, and repealing Regulation (EC) No 45/2001 and Decision No 1247/2002/EC.

2.4 Corporate planning and reporting

2.4.1 Corporate programming documents and corporate planning

In 2021, the SESAR JU made two amendments to the 2021–2023 SPD that were adopted by the Administrative Board. These procedures related to the reinscription of unused appropriations from previous years into the 2021 budget (first amendment) and the increase in payment appropriations (second amendment). The decisions of the Administrative Board regarding these amendments are listed in Section III.2.

Furthermore, in accordance with requirements of the framework financial regulation, the SESAR JU further developed its 2022–2024 SPD, which was adopted by the Administrative Board on 25 November 2021 (ADB(D)20-2021). This adoption included the approval of the 2022 annual work programme, the financing decision of the adoption of the 2022 budget, both under the SESAR 2020 scope, and the approval of the staff establishment plan for 2022. Although the entry into force of the new legal entity was foreseen, which would require a new type of annual work programme and budget, the SESAR JU management decided to develop and secure the adoption of the 2022–2024 SPD as a mitigation measure in case the legislative process leading to the set-up of the new entity was delayed and/or the annual work programme of that new legal entity could not be adopted on time. As the latter risk materialised, the SESAR 3 JU adopted a decision transferring the content of the 2022–2024 SPD and the related budget and staff establishment plan to the new entity, in order to ensure continuity of operations in the beginning of 2022.

Furthermore, an important element in planning activities was the development of the MAWP, which is summarised in Section I.3.1.

2.4.2 Corporate reporting

In 2021, the SESAR JU released its 2020 CAAR, which the Administrative Board approved through a written procedure on 21 June 2021 (ADB(D)11-2021).

During the reporting year, the SESAR JU also revised the H2020 indicators and addressed the final recommendation of the IAS, namely on the measurement of KPI 33 (see Annex III.1).

Moreover, the SESAR JU prepared and submitted implementation reports for 2021 in response to the two delegation agreements referred to in Section I.1, namely on CEF U-space demonstrations and on geofencing demonstrations, covering the audit activities during 2021. The SESAR JU made no payments relating to those projects in the reporting period.

The SESAR JU reported on its activities to the Administrative Board twice during 2021.

2.4.2.1 Leverage effect

Building on the clarifications on the leverage effect calculation methodology in the 2018 CAAR (Part I, Section 2.6.5, pages 144 and 145), the SESAR JU uses three methods to present the leverage of the SESAR JU:

1. the method used by the European Commission in the context of the interim evaluation;
2. a method that is a refinement of the interim evaluation method but also includes all activities of the SESAR JU;
3. the method used under H2020.

Some readers also expect to see a leverage that describes the contribution of the beneficiaries of SESAR 2020 grants against that of the EU. As the industrial programme is only a part of the responsibility and work undertaken by the SESAR JU, this must be calculated differently in order to be meaningful. A partnership leverage is also calculated and will be consistently reported on in this and future reports.

The set of leverage targets, the raw data and the calculation methods used are shown in Table 9 ([49]).

Table 9: Cumulative leverage for the programme and the SESAR JU

		Cumulative Leverage (Reporting)					Forecast
Partnership Leverage (SESAR Programme)		**2017 Adopted**	**2018 Adopted**	**2019 Reported**	**2020 Reported**	**2021 Estimate**	**Leverage**
1	Gross In-Kind contribution by Members	€126,547,889.00	€264,133,070.00	€370,110,780.00	€437,242,288.22	€559,715,721.27	€670,147,718.28
2	Co-Financing requested by Members	€70,472,006.00	€147,843,953.00	€208,815,125.38	€246,514,744.36	€316,483,057.59	€379,529,463.10
3	**Net In-Kind Contribution of Members**	**€56,075,883.00**	**€116,289,117.00**	**€161,295,654.62**	**€190,727,543.86**	**€243,232,663.68**	**€290,618,255.18**
4	Gross In-Kind contribution by Founding Member EUROCONTROL	€60,547,899.00	€122,744,297.00	€185,625,399.66	€227,991,936.58	€285,091,936.58	€347,089,251.31
5	Co-Financing requested by Founding Member EUROCONTROL	€945,174.00	€1,977,073.00	€3,057,148.98	€3,201,561.97	€3,701,561.97	€4,649,895.41
6	**Net In-Kind Contribution of Founding Member EUROCONTROL**	**€59,602,725.00**	**€120,767,224.00**	**€182,568,250.68**	**€224,790,374.61**	**€281,390,374.61**	**€342,439,355.90**
7	**Net In-Kind contribution by Founding Member EU**	€0.00	€0.00	€0.00	€0.00	€0.00	
8	**SJU Commitment Appropriations for Co-financing**	€180,610,284.00	€180,610,284.00	€211,872,274.36	€249,716,306.33	€320,184,619.56	€384,179,358.51
	of Members & Founding Member						
	Calculation Partnership Leverage = ((3)+(6)+(7))/(8)	**0.64**	**1.31**	**1.62**	**1.66**	**1.64**	**1.65**
	Calculation Partnership Leverage = ((3)+(6)+(7)+(8))/(8)	**1.64**	**2.31**	**2.62**	**2.66**	**2.64**	**2.65**
Union Body Leverage (SESAR JU)		**2017 Adopted**	**2018 Adopted**	**2019 Reported**	**2020 Reported**	**2021 Estimate**	
1	**Net Contribution of Members (inc. cash)**	**€58,713,893.00**	**€121,565,137.00**	**€167,890,679.62**	**€198,641,573.86**	**€256,032,560.68**	**€308,229,397.18**
2	**Net Contribution of EUROCONTROL (inc. cash)**	**€67,290,326.41**	**€132,638,367.78**	**€196,412,507.54**	**€240,563,230.40**	**€298,363,230.40**	**€360,707,211.23**
3	**Net In-Kind contribution by Founding Member EU**	**€0.00**	**€0.00**	**€0.00**	**€0.00**	**€0.00**	**€0.00**
	Finance Available for ER Open calls						
	Finance Available for VLD Open calls						
	Total Finance available for Open calls						
	5% contribution to Running Costs						
	Maximum Finance available for Open Calls						
	Forecast overall funding rate						
4	**Net In-Kind Contribution from Open calls (ER + VLD-Open)**	**€14,147,995.00**	**€14,147,995.00**	**€12,630,784.14**	**€17,440,689.39**	**€27,971,433.97**	**€27,971,433.97**
5	**Total EU Commitment Appropriations available to the SJU**	**€236,148,000.00**	**€348,711,000.00**	**€461,329,000.00**	**€585,000,000.00**	**€585,000,000.00**	**€585,000,000.00**
6	**EU Commitment Appropriations available to the SJU for ER**						
	Target Leverage by Regulation = ((1)+(2)+(3))/(5-6)						
	Target Leverage by Interim Evaluation = ((1)+(2)+(3))/(5)	**0.53**	**0.73**	**0.79**	**0.75**	**0.95**	**1.14**
	Calculation of SJU Union Body Leverage = ((1)+(2)+(3)+(4))/(5)	**0.59**	**0.77**	**0.82**	**0.78**	**1.00**	**1.19**
	Calculation of SJU Union Body Leverage = ((1)+(2)+(3)+(4)+(5))/(5)	**1.59**	**1.77**	**1.82**	**1.78**	**2.00**	**2.19**

Table 9 shows that, as reported in 2020, the actual leverage of the SESAR JU and the SESAR 2020 programme regularly progresses towards the targets in 2021.

2.5 Budgetary and financial management

2.5.1 Financial management

The primary focus in the area of financial management was the implementation of the budget.

In term of financial controls on the implementation of the budget, a large number of assessments and initiatives were conducted in 2021, based on the conclusion of the evaluation of consistency and completeness of the financial procedure initiated in 2020.

From the evaluation of financial information and documentation, taking into consideration risk management and quality controls, multiple actions were launched at the SESAR JU in term of roles' description and actors' designation, and in term of financial phases' description and workflow variety. Those initiatives allowed the consolidation of existing financial circuits' documentation into a manual

([49]) 2021 estimate is subject to receipt of validated financial figures from the Members in line with the reporting cycle.

of financial circuits relating to the SESAR JU budget implementation, with the information contained within this manual updated, along with the specific financial procedures.

The evaluation has also allowed a complete review to be undertaken of the process descriptions available in the field of finance and budget, along with the publication of updates or new processes.

2021 also saw the formal integration of financial transactions of the electronic workflows currently on the information and document management service (IDMS) platform until the full deployment of the 'Speedwell' application that is foreseen in 2022.

Monitoring via internal dashboards continued in 2021 with the enlargement of the activities covered.

Stronger scrutiny in terms of the accrual-based accounting (ABAC) workflow application's interventions on users' and access rights was ensured by the population of lists of actions of the SESAR JU local administrator.

2.5.2 Annual budget for 2021

The 2021 budget was adopted through the adoption of the 2021–2023 SPD in December 2020, and then modified through the following two amendments to the 2021–2023 SPD (see Section II.4).

1. The first amendment authorised the reinscription of unused appropriations from previous years and some limited increases of appropriation, in both commitment and payment, in order to take into account needs in expenditure that were not known at the time of the budget adoption.
2. The second amendment was necessary as the budgeted payment appropriations for wave 2 projects (reporting period 1) were underestimated. The second amended version of the SPD for 2021–2023 refers to the use of unused appropriations from previous years to cover this underestimation with an amendment to the budget being required for this purpose. In accordance with Article 12 of the SESAR JU financial rules, given the needs of the SESAR JU, the cancelled appropriations may be entered in the estimates of revenue and expenditure for up to the following three financial years.

The 2021 budget, as modified through the second amendment to the 2021–2023 SPD, established an amount of EUR 33 147 925 in commitment appropriations and EUR 68 181 399 in payment appropriations, representing a 76 % decrease in commitment appropriations and a 46 % decrease in payment appropriations.

The 2021 budget included revenue (cash forecasted to be received, additional appropriations coming from carry-overs and internal assigned revenues) of EUR 33 147 925 and payment appropriations (cash forecasted to be spent) of EUR 68 181 399.

In terms of expenditure, the budget presented total available commitment appropriations of EUR 34 828 358 and total payment appropriations of EUR 69 861 831, made up as follows ([50]):

- initial commitment appropriations of EUR 11 344 673, amending budgets for EUR 21 803 252, carry-overs and assigned revenue for an amount of EUR 1 680 433;
- initial payment appropriations of EUR 46 785 481, amending budgets for EUR 21 395 917, carry-overs and assigned revenue for an amount of EUR 1 680 433.

([50]) Including initial budget, amending budgets, transfers and additional appropriations (carry-overs and assigned revenue).

2.5.3 Implementation of the budget for 2021

2.5.3.1 Revenue

Table 10 provides a breakdown of revenues by source. The following paragraphs provide details about the specific programmes.

Table 10: 2021 budget revenues by source

SESAR 1 + SESAR 2020

all figures in EUR	1	2	3=2/1	4	5	6=5/4	7	8
Type of revenue	**Commitment appropriations (1)**	**Actual Revenues established/ carried over**	***% of budget***	**Payment appropriations (2)**	**PA execution**	***% of budget***	**Outstanding (from 2021 only)**	**Outstanding (Total)**
Contribution from the European Union (1)	0	94.525.511	*0,0%*	41.301.467	41.287.480	*100,0%*	53.238.031	102.065.905 (2)
Assigned Revenues	0	0	*0,0%*	0	0	*0,0%*	0	0
Contribution from Eurocontrol	1.200.000	776.351	*64,7%*	1.200.000	776.351	*64,7%*	0	9.727.888
Contributions from other Members	3.087.011	1.834.376	*59,4%*	2.110.408	1.833.797	*86,9%*	579	9.760.044
Other sources of contribution and revenue	0	0	*0,0%*	0	0	*0,0%*	0	0
C2 inscriptions	28.860.914	1.751.754	*6,1%*	23.569.523	1.680.433	*7,1%*	71.322	0
TOTAL REVENUE	**33.147.925**	**98.887.992**	***298,32%***	**68.181.399**	**45.578.061**	***66,85%***	**53.309.931**	**121.553.838**

(1) Contributions from the EU only in payment appropriations - The EU commitment appropriation was received in its totality (EUR 585 million)
(2) RAL ("reste à liquider") from the EU in payment appropriations

SESAR 1

all figures in EUR	1	2	3=2/1	4	5	6=5/4	7	8
Type of revenue	**Commitment appropriations**	**Actual Revenues established/carried over**	***% of budget***	**Payment appropriations**	**Actual Revenues received**	***% of budget***	**Outstanding (from 2021 only)**	**Outstanding (Total)**
Contribution from the European Union			*0,0%*			*0,0%*		
Contribution from Eurocontrol			*0,0%*			*0,0%*		
Contributions from other Members		(292.513)	*0,0%*		(292.513)	*0,0%*		
Other sources of contribution and revenue			*0,0%*			*0,0%*		
TOTAL REVENUE	**0**	**-292.513**	*0,0%*	**0**	**-292.513**	*0,00%*	**0**	**0**

SESAR 2020

all figures in EUR	1	2	3=2/1	4	5	6=5/4	7	8
Type of revenue	**Commitment appropriations**	**Actual Revenues established/carried over**	*%of budget*	**Payment appropriations**	**Actual Revenues received**	*%of budget*	**Outstanding (from 2021 only)**	**Outstanding (Total)**
Contribution from the European Union (1)		94.525.511	*0,0%*	41.301.467	41.287.480	*100,0%*	53.238.031	102.065.905 (2)
Assigned Revenues			*0,0%*			*0,0%*	0	
Contribution from Eurocontrol	1.200.000	776.351	*64,7%*	1.200.000	776.350,8	*64,7%*	0	9.727.888
Contributions from other Members	3.087.011	2.126.889	*68,9%*	2.110.408	2.126.310,0	*100,8%*	579	9.760.044
Other sources of contribution and revenue			*0,0%*			*0,0%*	0	
C2 inscriptions	28.860.914	1.751.754	*6,1%*	23.569.523	1.680.432,6	*7,1%*	71.322	
TOTAL REVENUE	**33.147.925**	**99.180.505**	***299,2%***	**68.181.399**	**45.870.573**	*67,28%*	**53.309.931**	**121.553.838**

(1) Contributions from the EU only in payment appropriations - The EU commitment appropriation was received in its totality (EUR 585 million)
(2) RAL ("reste à liquider") from the EU in payment appropriations

2.5.3.1.1 SESAR 2020

The total revenue received in 2021 (for the SESAR 2020 programme) amounted to EUR 45 870 573 ([51]), made up of an EU contribution, a contribution from the European Free Trade Association (EFTA), financial contributions from the other members and other contributions:

- the total EU contribution was EUR 41 287 480, made up of:
  - administrative: EUR 3 326 672,
  - operational: EUR 37 960 808.
- other contributions totalled EUR 4 583 093, made up of:
  - EUROCONTROL: EUR 776 351,
  - other members: EUR 2 126 310,
  - other contributions ([52]): EUR 1 680 432.

2.5.3.1.2 SESAR 1

The total revenue received was negative in 2021 (EUR 292 513), owing to the financial closure of the SESAR 1 programme and the reimbursement of excess financial contributions (the three remaining members that were not reimbursed in 2020)([53]).

2.5.3.2 Expenditure

The 2021 execution rate was 26.97 % in the case of available commitment appropriations and 90.37 % in the case of payment appropriations.
In terms of expenditure, total commitments amounted to EUR 9 392 533 (26.97 %) of the total available appropriations budget). This very low rate of execution is mainly due to title 4, which gathers the unused appropriations from previous years not required in the current year but that are needed

([51]) The SESAR JU submitted an additional debit note on 16 December 2021 for 2022 EU contributions amounting to EUR 53 238 031, which was cashed on 17 January 2022. Therefore, the amount of the debit note is presented as the actual revenue established in 2021.
([52]) Such as reimbursements from the H2020 Guarantee Fund, recoveries after *ex ante* audits on projects, late interest, etc.
([53]) For detailed explanation on the process related to the reimbursement of SESAR 1 excess of financial contributions refer to paragraph II.5.5. Financial closure of the SESAR 1 programme.

to cover the needs of the SESAR 2020 programme until 2024 (unused commitment appropriations at year-end: EUR 21 307 358.

In payments, the rate of 88.4 % was mainly influenced by the low consumption on Title 2.

The total payments executed amount to EUR 63 131 778, that is, 90.37 %.

Some operational spending have to be postponed to the beginning of 2022 due to a lack of cash at year-end (cash balance at year-end: EUR 592 241). The reason for the commitments rate of 78.9 % and the low payment consumption under title 2 is the low rate of execution under:

- 'security maintenance' (29.3 %), with non executed works for an amount of EUR 65 000 (security works foreseen but not executed) and therefore no related payment (23.2%);
- 'legal support', with an unexecuted amount of EUR 46 010 both in commitment(8.0 %) and payment (8.0%);
- 'tax audit and accounting service' (30.1 %), with an unexecuted amount of EUR 338 988 (the audit for the U-space projects was estimated at EUR 325 000 and the actual costs amounted to EUR 41 858). This impacted the implementation rate both in commitment (30.1%) and payment (26.38%);
- 'realisation of public relations activities and material': due to the COVID-19 crisis a lot of events foreseen were postponed to 2022 and not paid in 2021 (out of EUR 445 146 of appropriation available only EUR 180 000 was paid (40.3%).

In order to ensure the adequate management of the budget appropriations, the Executive Director *ad interim* authorized during 2021 budget transfers within the limits defined in Article 25(1) of the SESAR JU Financial Rules([54]).

Table 11 provides a breakdown of expenditures by title for SESAR 2020 and Table 12 sets out the number and value of budget transfers.

([54]) Article 25(1) of the SESAR JU Financial Rules (Administrative Board decision ADB(D)21-2019) establishes that "The Executive Director may transfer appropriations: (a) from one title to another up to a maximum of 10 % of the appropriations for the financial year shown on the line from which the transfer is made; (b) from one chapter to another and within each chapter without limit.

Table 11: Breakdown of expenditures by title for SESAR 2020 programme

SESAR 2020

all figures in EUR	1	2	3=2/1	4	5	8=7/6	10	5	7
Type of expenditure	**Final Commitment appropriations**	**Commitments**		**Payment appropriations**	**Payments**		**Commitments still to be paid**	**Payments (against commitments of the year)**	**Payments (against previous years' commitments)**
	Budget 2021		*% of budget*	*Budget 2021*		*% of budget*	*(Total)*		
Staff Expenditure	5.631.262	4.841.782	*86,0%*	5.631.262	4.825.792	*85,7%*	148.262	4.693.519	132.273
Administrative Expenditure	3.693.767	2.915.846	*78,9%*	3.693.767	2.158.567	*58,4%*	1.040.173	1.891.611	266.956
Operational Expenditure	*4.195.994*	*1.634.905*	*39,0%*	*60.536.802*	*56.147.419*	*92,7%*	*92.469.725*	*888.886*	*55.258.533*
1. Providing strategic steering to the SESAR programme	*1.100.000*	*935.000*	*85,0%*	*1.448.507*	*1.382.920*	*95,5%*	*2.745.630*	*188.981*	*1.193.939*
2. Deliver exploratory research	*154.183*	*1.839*	*1,2%*	*14.624.142*	*11.647.174*	*79,6%*	*33.118.221*	*1.839*	*11.645.335*
3. Deliver industrial research and validation	*1.450.890*	*24.612*	*1,7%*	*37.599.533*	*36.443.915*	*96,9%*	*35.881.463*	*24.612*	*36.419.303*
4. Deliver very large-scale demonstration activities	*179.422*		*0,0%*	*5.541.528*	*5.362.106*	*96,8%*	*19.748.935*		*5.362.106*
5. Deliver SESAR outreach	*1.311.500*	*673.454*	*51,3%*	*1.323.093*	*1.311.304*	*99,1%*	*975.476*	*673.454*	*637.850*
Unused Appropriations not required in current Year	21.307.334		*0,0%*	0					
TOTAL EXPENDITURE	**34.828.358**	**9.392.533**	***26,97%***	***69.861.831***	**63.131.778**	***90,37%***	**93.658.160**	**7.474.016**	**55.657.762**
TOTAL REVENUE					**45.870.573**				
BUDGET RESULTS					**(17.261.205)**				

Table 12: Number and value of budget transfers

Transfers Commitment Appropriations

		Credit Local Key	Credit Central Key	Credit User Reference	Acceptance Date	TAMC
11-0	C2	SES.26930	CSAR20213721000237	TRANSFER FROM MISSIONS BL 1510 TO COMMS BL 2310 TO COVER TMAB SC6	22-12-2021	-45.146,20
	C8	SES.26701	CSAR20213721000027	3721000027	08-01-2021	
11-0						-45.146,20
21-0	C1	SES.26838	CSAR20213721000164	TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2730-C1-SESAR TO BUDGET LINE CSAR-B2021-2710-C1-SESAR	30-04-2021	30.000,00
21-0	C1	SES.26905	CSAR20213721000223	TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2710-C1-SESAR TO BUDGET LINE CSAR-B2021-2730-C1-SESAR	22-10-2021	-30.000,00
21-0	C1	SES.26915	CSAR20213721000232	TRANSFERT TO ICT SUPPORT BUDGET LINE (2750) TO COVER NOVEMBER AND DECEMBER INVOICES	15-12-2021	-3.000,00
21-0	C2	SES.26899	CSAR20213721000218	1ST TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2710-C2-SESAR TO BUDGET LINE CSAR-B2021-2720-C2-SESAR	15-10-2021	-5.619,98
21-0	C2	SES.26930	CSAR20213721000237	TRANSFER FROM MISSIONS BL 1510 TO COMMS BL 2310 TO COVER TMAB SC6	22-12-2021	45.146,20
21-0						36.526,22
22-0	C2	SES.26899	CSAR20213721000218	1ST TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2710-C2-SESAR TO BUDGET LINE CSAR-B2021-2720-C2-SESAR	15-10-2021	5.619,98
22-0						5.619,98
23-0	C1	SES.26838	CSAR20213721000164	TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2730-C1-SESAR TO BUDGET LINE CSAR-B2021-2710-C1-SESAR	30-04-2021	-30.000,00
23-0	C1	SES.26905	CSAR20213721000223	TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2710-C1-SESAR TO BUDGET LINE CSAR-B2021-2730-C1-SESAR	22-10-2021	30.000,00
23-0						0,00
25-0	C1	SES.26915	CSAR20213721000232	TRANSFERT TO ICT SUPPORT BUDGET LINE (2750) TO COVER NOVEMBER AND DECEMBER INVOICES	15-12-2021	3.000,00
25-0						3.000,00
					Sum:	0,00

Transfers Payment Appropriations

		Credit Local Key	Credit Central Key	Credit User Reference	Acceptance Date	TAMC
11-0	C2	SES.26930	CSAR20213721000237	TRANSFER FROM MISSIONS BL 1510 TO COMMS BL 2310 TO COVER TMAB SC6	22-12-2021	-45.146,20
11-0						-45.146,20
21-0	C1	SES.26838	CSAR20213721000164	TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2730-C1-SESAR TO BUDGET LINE CSAR-B2021-2710-C1-SESAR	30-04-2021	30.000,00
21-0	C1	SES.26905	CSAR20213721000223	TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2710-C1-SESAR TO BUDGET LINE CSAR-B2021-2730-C1-SESAR	22-10-2021	-30.000,00
21-0	C1	SES.26915	CSAR20213721000232	TRANSFERT TO ICT SUPPORT BUDGET LINE (2750) TO COVER NOVEMBER AND DECEMBER INVOICES	15-12-2021	-1.250,00
21-0	C2	SES.26899	CSAR20213721000218	1ST TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2710-C2-SESAR TO BUDGET LINE CSAR-B2021-2720-C2-SESAR	15-10-2021	-5.619,98
21-0	C2	SES.26930	CSAR20213721000237	TRANSFER FROM MISSIONS BL 1510 TO COMMS BL 2310 TO COVER TMAB SC6	22-12-2021	45.146,20
21-0						38.276,22
22-0	C2	SES.26899	CSAR20213721000218	1ST TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2710-C2-SESAR TO BUDGET LINE CSAR-B2021-2720-C2-SESAR	15-10-2021	5.619,98
22-0						5.619,98
23-0	C1	SES.26838	CSAR20213721000164	TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2730-C1-SESAR TO BUDGET LINE CSAR-B2021-2710-C1-SESAR	30-04-2021	-30.000,00
23-0	C1	SES.26905	CSAR20213721000223	TRANSFER 2021 FROM BUDGET LINE CSAR-B2021-2710-C1-SESAR TO BUDGET LINE CSAR-B2021-2730-C1-SESAR	22-10-2021	30.000,00
23-0						0,00
25-0	C1	SES.26915	CSAR20213721000232	TRANSFERT TO ICT SUPPORT BUDGET LINE (2750) TO COVER NOVEMBER AND DECEMBER INVOICES	15-12-2021	1.250,00
25-0						1.250,00
					Sum:	0,00

2.5.4 SESAR 2020 multiannual budget execution

The execution rate, in terms of revenues committed (revenues established and recognised), was 98.6 %, while 82.6 % of payments were executed.

Cumulative validated in-kind contributions amounted to EUR 428 486 342 (60.1 % of the total estimated in-kind contributions based on the SESAR JU membership agreement). This in-kind contribution validation concerns activities performed by the SESAR JU members other than the EU from the end of 2016 until the end of 2020 (Table 13).

Table 13: SESAR JU Multi-annual revenues

Multi-annual revenue

all figures in EUR	1	2							3	4=2-3
I. CASH CONTRIBUTIONS	SESAR 2020 Progamme Maximum	Total Entitlements ('Commitments')	Revenues/Contributions actually received ('Payments') 2016	2017	2018	2019	2020	2021	Total 2016-2021	Open Entitlements still to be received
EUROPEAN UNION CONTRIBUTION *H2020 funds*	585.000.000	585.000.000	56.519.225	75.497.252	84.184.652	113.733.525	111.711.961	41.287.480	482.934.095	102.065.905
EUROPEAN UNION CONTRIBUTION *Assigned revenue*	11.300.000	11.300.000		650.000	4.000.000	402.657	6.000.000		11.052.657	0
CONTRIBUTION FROM EUROCONTROL	25.000.000	15.272.112		6.682.000	5.189.144	776.351	1.848.266	776.351	15.272.112	9.727.888
CONTRIBUTION FROM OTHER MEMBERS	18.466.056	8.706.012			2.546.435	2.729.585	1.303.103	2.126.889	8.706.012	9.760.044
OTHER REVENUE	0	10.297.326		23.774	80.633	5.148.227	3.292.937	1.679.854	10.225.426	71.900
Total CASH Contributions	639.766.056	630.575.450	56.519.225	82.853.026	96.000.864	122.790.345	124.156.268	45.870.573	528.190.301	121.625.738
Cumulative Budget implementation rates (of Prog. Max.):		*98,6%*							*82,6%*	
II. IN-KIND CONTRIBUTIONS IKC (validated by the SJU)										
IKC from EUROCONTROL	433.418.444	230.777.228			59.602.725	66.067.916	60.579.895	44.526.692	230.777.228	202.641.216
IKC from OTHER MEMBERS	280.024.950	192.232.060			54.234.818	60.753.342	45.974.388	31.269.511	192.232.060	87.792.890
Total IN-KIND Contributions	713.443.394	423.009.287	0	0	113.837.543	126.821.258	106.554.283	75.796.203	423.009.287	290.434.107
Cumulative Budget implementation rates (of Prog. Max.):		*59,3%*							*59,3%*	
III. TOTAL CONTRIBUTIONS (I.+II.)	1.353.209.450	1.053.584.737	56.519.225	82.853.026	209.838.407	249.611.603	230.710.551	121.666.776	951.199.588	412.059.845
Cumulative Budget implementation rates (of Prog. Max.):		*77,9%*							*70,3%*	

On the expenditure side, the commitments made reached 95.4 % of the total programme forecasts and payments reached 81.9 % of the total programme forecasts (Table 14).

Table 14: SESAR JU Multi-annual expenditure

Multi-annual expenditure

all figures in million EUR	1	2							3	4=2-3
I. Expenditure Budget Titles:	SESAR 2020 Programme Maximum	Total Commitments made	PAYMENTS							Open Commitments (RAL)
			2016	2017	2018	2019	2020	2021	Total 2016-2021	
Running Costs *(Titles 1 & 2)*	70.172.152	40.198.282		6.089.087,56	9.270.137,86	7.773.835,10	8.142.249,47	6.984.359,03	38.259.669	506.276
Operational Expenditure Non-Members (Title 3)	171.593.904	174.934.136	9.919.493	15.443.239	15.440.464	15.904.159	38.918.738	19.703.504	115.329.597	87.404.416
Operational Expenditure Members *(Title 3)*	398.000.000	395.500.073	40.000.000	40.827.960	52.074.908	126.941.403	74.145.998	36.443.915	370.434.184	59.873.440
TOTAL Expenditure :	639.766.056	610.632.491	49.919.493	62.360.287	76.785.510	150.619.397	121.206.985	63.131.778	524.023.450	147.784.132,38
Cumulative Budget implementation rates (of Prog. Max.):		*95,4%*							*81,9%*	
II. Budget Results										
Revenue *(see Multi-annual revenues)*	639.766.056	630.575.450	52.583.682	85.517.256	119.157.832	166.234.583	139.060.431	63.724.019	626.277.803	4.297.647
Cumulative Budget Result *(Revenues /. Expenditure)*	*0*	*19.942.958*	*2.664.190*	*23.156.969*	*42.372.322*	*15.615.186*	*17.853.446*	*592.241*	*102.254.353*	*143.486.486*

2.5.5 Financial closure of the SESAR 1 programme

2.5.5.1 Reimbursement of excess financial contributions

The decision to reimburse the cash remaining from the SESAR 1 programme was submitted to the Administrative Board of the SESAR JU on 7 May 2020, and was adopted on 8 October 2020 following a positive opinion from the Commission on the same day.

After consultation of DG BUDGET, the following operations have to be implemented to reimburse the excess of financial contributions to the SESAR JU Members:

1. “Hors budget” payment request

2. Regularisation of this “Hors budget” payment request through a regularisation recovery order to post the negative budget revenue on the income line(s) that were used for the initial contributions. As a result of this approach the aggregated (for all years) budget revenue and expenditure of SESAR 1 will be correct.

The SESAR JU reimbursed the EU, EUROCONTROL and the other members in 2020.

On 31 December 2020, all but three payments had been processed, for an amount of EUR 30 474 585.55 (out of EUR 30 767 098, that is, 99 %).

2.5.5.2 Overview of SESAR 1 programme execution

The final overall programme execution rate was 90.0 % and for title 3 only it was 92.8 % (Table 15).

Table 15: Budget execution for the SESAR 1 programme

	Commitment made	Payments made	Total programme	% Payments execution
Title 1	40.596.071	40.596.071	55.000.000	73,8%
Title 2	24.838.991	24.838.991	42.824.089	58,0%
Title 3	737.729.330	737.729.330	795.000.000	92,8%
Total	803.164.392	803.164.392	892.824.089	90,0%

The final reimbursements of excess financial contributions, to three members, were executed in January and February 2021 (Table 16). The SESAR 1 programme is therefore totally closed.

Table 16: Final reimbursements of excess financial contributions executed in 2021

	Cash 01/01/2020	Revenue received in 2020	Cash used during the year 2020	Cash at year end 2020	Cash used during the year 2021	Cash at year end 2021
	30.689.661			292.513		0
Ex-post audit		81.564,25	(4.127,50)			
Reimbursement of excess of financial contributions		323.835,49	(30.798.421,04)		(292.513)	
EU			(23.897.454,25)			
EUROCONTROL			(4.778.826,05)			
Other Members		323.835,49	(2.122.140,74)		(292.513)	
	30.689.661	**405.399,74**	**(30.802.548,54)**	**292.513**	**(292.513)**	**0**

2.5.6 Budget out-turn

As the SESAR JU is a multiannual programme (with a limited lifetime and fixed total budget ceilings), unused payment appropriations at the end of one budgetary year are not cancelled but inscribed as a budget result in the revenues of the subsequent budget. The budget result for 2021 (i.e. the total revenue received of EUR 45 578 061 minus the total payments of EUR 63 131 778) amounts to a deficit of EUR 17 553 718 (a deficit of EUR 17 261 205 for SESAR 2020 and a deficit of EUR 292 513 for SESAR 1). This deficit has been covered by the cash available at the beginning of 2021. The 2021 cumulative surplus that remains within the SESAR JU amounts to EUR 592 241 (of which EUR 592 241 relates to SESAR 2020 and EUR 0 relates to SESAR 1 ([55]); Tables 17–20).

([55]) A total of EUR 292 513 remained to be reimbursed at the end of 2020. The final three members were reimbursed in January and February 2021.

Table 17: Cumulative budget out-turn SESAR 1 and SESAR 2020 Programmes

SESAR 1 + SESAR 2020

all figures in EUR	2021	2020	2019
REVENUE RECEIVED FOR THE YEAR			
Contribution from the European Union SESAR1		(23.897.454)	
Contribution from the European Union SESAR2020	41.287.480	117.711.961	114.136.182
Contribution from Eurocontrol	776.351	(3.641.583)	1.848.266
Contributions from other Members	1.834.376	(495.202)	2.729.585
Other sources of contribution and revenue SESAR1	0	81.564	915.510
Other sources of contribution and revenue SESAR2020	1.679.854	3.292.937	5.148.227
TOTAL REVENUE (1)	**45.578.061**	**93.052.223**	**124.777.771**
TOTAL PAYMENTS MADE FOR THE YEAR			
Staff Expenditure SESAR2020	(4.825.792,06)	(5.192.405)	(5.325.094)
Administrative Expenditure SESAR1	0,00	0	0
Administrative Expenditure SESAR2020	(2.158.566,84)	(2.945.854)	(2.448.741)
Operational Expenditure SESAR1	0,00	(4.128)	(885.282)
Operational Expenditure SESAR2020	(56.147.419,14)	(113.064.735)	(142.845.562)
TOTAL EXPENDITURE (2)	**(63.131.778)**	**(121.207.122)**	**(151.504.679)**
EXCHANGE RATE DIFFERENCES	**(0)**	**(3.990)**	
BUDGET SURPLUS of the year (3)=(1)-(2) SESAR1	***(292.513)***	***(30.397.149)***	***30.228***
BUDGET SURPLUS of the year (3)=(1)-(2) SESAR2020	***(17.261.205)***	***2.238.260***	***(26.757.136)***
Total Budget Surplus previous year (4) SESAR1	**292.513**	**30.689.661**	**30.659.434**
Total Budget Surplus previous year (4) SESAR2020	**17.853.446**	**15.615.186**	**42.372.322**
NEW TOTAL BUDGET SURPLUS (5)=(3)+(4) SESAR1	***0***	***292.513***	***30.689.661***
NEW TOTAL BUDGET SURPLUS (6)=(3)+(4) SESAR2020	***592.241***	***17.853.446***	***15.615.186***
TOTAL BUDGET OUTTURN (7)=(5)+(6)	**592.241**	**18.145.958**	**46.304.847**

Table 18: Cumulative budget out-turn SESAR 1 Programme

SESAR 1

all figures in EUR	2021	2020	2019
REVENUE RECEIVED FOR THE YEAR			
Contribution from the European Union SESAR1		(23.897.454)	
Contribution from Eurocontrol		(4.778.826)	
Contributions from other Members	(292.513)	(1.798.305)	
Other sources of contribution and revenue		81.564	915.510
TOTAL REVENUE (1)	**(292.513)**	**(30.393.021)**	**915.510**
TOTAL PAYMENTS MADE FOR THE YEAR			
Staff Expenditure SESAR1			
Administrative Expenditure SESAR1			
Operating Expenditure SESAR1		(4.128)	(885.282)
TOTAL EXPENDITURE (2)	**0,00**	**(4.127,50)**	**(885.282,26)**
BUDGET SURPLUS of the year (3)=(1)-(2) SESAR1	***(292.513)***	***(30.397.149)***	***30.228***
Total Budget Surplus previous year (4) SESAR1	**292.513**	**30.689.661**	**30.659.434**
Total Budget Surplus previous year (4) SESAR2020			
NEW TOTAL BUDGET SURPLUS (5)=(3)+(4) SESAR1	***0***	***292.513***	***30.689.661***

Table 19: Cumulative budget out-turn SESAR 2020 Programme

SESAR 2020			
all figures in EUR	2021	2020	2019
REVENUE RECEIVED FOR THE YEAR			
Contribution from the European Union SESAR2020	41.287.480	117.711.961	114.136.182
Contribution from Eurocontrol	776.351	1.137.244	1.848.266
Contributions from other Members	2.126.889	1.303.103	2.729.585
Other sources of contribution and revenue	1.679.854	3.292.937	5.148.227
TOTAL REVENUE (1)	**45.870.573**	**123.445.245**	**123.862.261**
TOTAL PAYMENTS MADE FOR THE YEAR			
Staff Expenditure SESAR2020	(4.825.792)	(5.192.405)	(5.325.094)
Administrative Expenditure SESAR2020	(2.158.567)	(2.945.854)	(2.448.741)
Operating Expenditure SESAR2020	(56.147.419)	(113.064.735)	(142.845.562)
TOTAL EXPENDITURE (2)	**(63.131.778,04)**	**(121.202.994,69)**	**(150.619.396,75)**
EXCHANGE RATE DIFFERENCES	**(0,13)**	**(3.990,18)**	
BUDGET SURPLUS of the year (3)=(1)-(2) SESAR2020	***(17.261.205)***	***2.238.260***	***(26.757.136)***
Total Budget Surplus previous year (4) SESAR2020	**17.853.446**	**15.615.186**	**42.372.322**
NEW TOTAL BUDGET SURPLUS (5)=(3)+(4) SESAR2020	***592.241***	***17.853.446***	***15.615.186***

Table 20: Budget out-turn and cancellation of appropriations

Budget out-turn	N – 3* (2019)	N – 2* (2020)	N – 1* (2021)
Reserve from the previous year's surplus (+)	73 031 756	46 304 847	18 145 958
Revenue actually received (+)	124 777 771	93 052 223	45 578 061
Payments made (–)	(151 504 679)	(121 207 122)	(63 131 778)
Carry-over of appropriations (–)			
Cancellation of appropriations carried over (+)			

Adjustment for carry-over of assigned revenue appropriations from previous year (+)			
Exchange rate differences (+/–)		(3 990)	
Adjustment for negative balance from previous year (–)			
Total	46 304 847	18 145 958	592 241

NB: *N is the year covered by the programming document drafted in N – 1 (as per Article 32).

2.6 Procurement and contracts

During 2021, the SESAR JU effectively implemented its procurement plan (as per Annex XII of the 2020–2022 SPD).

Owing to its focus on the transition process, the SESAR JU limited its maximum number of procurement procedures and dealt with 10 procurement procedures, including six very low-value procurements. In addition, the SESAR JU signed six interinstitutional framework service contracts, two direct service contracts, eight specific contracts implementing SESAR JU framework contracts / interinstitutional agreements and one prize.

These numbers demonstrate, among other things, the continued commitment of the SESAR JU to reinforcing its synergies with other EU institutions in the field of procurement in the interest of sound financial management.

In addition, the SESAR JU signed ninety amendments to its contracts, specific contracts, memoranda of understanding and SLAs, mainly as a consequence of the transition towards SESAR 3.

All procedures were carried out in compliance with the SESAR JU's financial rules to ensure respect for transparency, fair competition among suppliers and the most efficient use of SESAR JU funds. The procurement procedures supported the SESAR JU objectives transversally.

In 2021, the onboarding of the SESAR JU in e-tendering and e-submission marked a watershed in its procurement process modernisation. In addition, in order to manage and ensure the timely implementation of procurement activities to support the SESAR JU objectives, the SESAR JU continued to use a contract action planning tool to record all of the procurement/contract activities. This file is updated on a weekly basis in coordination with operational initiating agents (OIAs) and the corporate management team. This planning tool is a repository of all procurement activities planned in the SPD and of activities unforeseen at the time of the adoption of the SPD upon validation of the corporate management team, and details the timeline for implementation of these activities on the basis of SESAR JU needs and applicable rules.

2.7 Information technology and logistics

2.7.1 Information and communication technologies management

SESAR JU operations are supported by an ICT system composed of the following elements:

- infrastructure and services acquired or rented through EUROCONTROL under Schedule 4 of the SESAR JU–EUROCONTROL agreement, for instance the network, support services, email system, etc.;
- tools and services acquired through the European Commission, such as ABAC for finance, SyGMa-COMPASS for grant management, SYSPER for Agencies for HR management, etc.;
- direct contracts set up by the SESAR JU or that form part of joint acquisitions with other EU agencies.

In 2021, faced with the continued COVID-19 crisis and the teleworking measures that lasted for several months, the SESAR JU's ICT system was closely monitored to guarantee the continuity of services and the availability to end users.

The ICT system was central to the continuity of the SESAR JU's operations.

Also in 2021, EUROCONTROL changed its IT providers as the consequence of a procurement procedure. During the first quarter of the year, the SESAR JU participated in the migration of the services from the previous to the new suppliers and significantly contributed to improving the quality of the services that degraded initially as the result of the intake by the new suppliers.

The successful provision of ICT services was enabled by implementing the provisions of Schedule 4 of the SESAR JU–EUROCONTROL agreement and agreements with the European Commission for the provision of ICT services. Continuous process improvements and strong working relationships between the SESAR JU ICT service and its suppliers, combined with new initiatives for transformation, innovation and risk mitigation, all helped to ensure that a high-quality support service was delivered throughout the year while keeping the cost of the support service stable and under control (between –5 % and –10 % compared with the previous year, thanks to the new contracts between EUROCONTROL and its suppliers).

Transformation projects, all of which were approved by the SESAR JU QICT Committee, which includes representatives from all SESAR JU sectors, focused particularly on guaranteeing the continuity of the service and minimising the risk of system failure in the event of disasters or major incidents. To this end, some outdated equipment, such as laptops, was replaced and remote monitoring capabilities were reinforced during the teleworking period. In addition, extensive fall-back testing was performed on the connectivity lines between the SESAR JU, EUROCONTROL and the internet by involving the local telephony provider, Proximus.

A couple of transformation projects planned for 2021 were not delivered because of the global shortage of parts, as those initiatives were mainly about hardware. However, mitigation actions were put in place by extending the maintenance contracts with the vendors. However, the two undelivered projects were compensated by other initiatives that were delivered, such as the preparatory work for the implementation of the Microsoft365 infrastructure.

A list of candidate transformation projects to be carried out in 2022 was submitted to the QICT Committee by the end of the year for information. The list of transformation projects was drawn up in consultation with service providers and will be subject to a prioritisation exercise early in 2022.

2.7.2 Facilities management

In 2021, work continued on a number of initiatives in the SESAR JU's premises in Brussels to maintain the productivity, safety and efficiency of the working environment and facilities offered to SESAR JU staff.

In particular, as a result of the COVID-19 pandemic, the facilities team was tasked with ensuring that the premises were safe for staff to use when lockdown regulations permitted. The team successfully implemented the necessary measures and tools to ensure the safety of staff members and others physically present on the premises. The facilities team monitored the occupancy levels and the presence of staff at the SESAR JU's premises, based on the rules and recommendations of the European Commission and the Belgian authorities.

The open call for tender SJU/LC/159-CFT was published during Q1 2021 for security services, which led to the signing of one service contract for lot 1 related to guarding. For lot 2 (related to the monitoring of alarm signals/messages, interventions on premises after alarm signals, and the maintenance of the security systems), no suitable tenders were received. Lot 2 was therefore cancelled and a negotiated procedure was launched leading to the extension of the existing contract (SJU/LC/327-CTR.2).

The facilities team has performed assessments in view of the possible change of premises of the SESAR JU. These include a comparison of the different options for changing SESAR JU premises, an external assessment (including an opportunity study, a commuting study and an evaluation of the cost of reestablishment of the premises) and a staff assessment (staff survey).

In 2021, the SESAR JU's insurance contracts were renewed with coherence in respect of coverage.

Finally, in Q3 2021, stocktaking was concluded successfully.

2.7.3 Travel coordination

In 2021, as a result of the continuous COVID-19 crisis and the ongoing severe restrictions to travel in Europe and globally, the number of missions performed by SESAR 3 JU staff dropped again: 27 missions took place in 2021 compared with 82 missions in 2020 and 244 in 2019 (not including missions related to the activities managed by the Programme Management Unit under the SESAR JU–EUROCONTROL agreement).

Of the 27 missions that took place in 2021, 13 (48 %) were related to transversal steering activities (strategic area of operation 1) and 10 (37 %) were related to SESAR outreach (strategic area of operation 5). Figure 16 shows all areas of operation.

Mission management was executed on time and in line with the rules of the European Commission's mission guide.

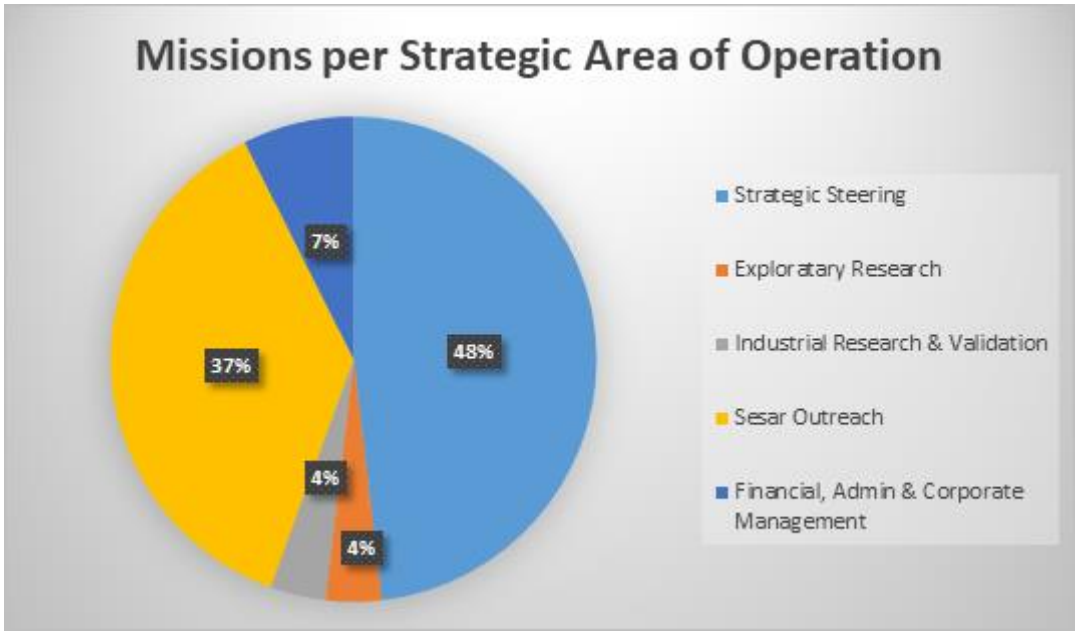


Figure 16: Breakdown of SESAR JU missions in 2021 by strategic area of operation

2.8 Human resources management

The SESAR JU-approved 2021 staff establishment plan allows for 38 temporary or contract agents and two seconded national experts (SNEs), as set out in the annual general budget of the European Union for the European Commission.

The staff establishment plan and its realisation are presented in Annex II.

The effective allocation of staff resources also remained a priority for the SESAR JU during 2021. Efforts were focused on the professional and career development of its staff, in addition to ensuring that allocated staff resources were used in the most economic, efficient and effective way.

In 2021, the SESAR JU conducted its appraisal exercise in accordance to the SESAR JU implementing rules, and was able to conduct the reclassification exercise, as a result of which eight temporary agents were reclassified.

The vacancy rate at the end of 2021 was 7.5 %. It should be noted that, as the SESAR JU staff establishment plan has only 37 positions plus one contract agent position and two SNE positions, each move in staff counts for more or less 2.5 %.

During the final quarter of 2020, the selection processes (internal and external) for the vacant positions of 'facility coordinator' and 'planning and reporting officer' were launched in order to create reserve lists. The contract with the successful candidate for the post of facility coordinator was signed in February 2021 (for this position, which was filled externally, the recruitment process was completed in March 2021 with the arrival of the selected candidate). The new planning and reporting officer, who was also an external recruit, joined the organisation in June 2021.

The Executive Director resigned with the effective date of 5 July 2021 and was replaced, *ad interim*, by the Chief Financial Officer, Mr Richard Frizon. The selection process was launched by the Directorate-General for Mobility and Transport in the final quarter of 2021.

SYSPER for Agencies, the HR management system developed by the European Commission, was successfully implemented in the SESAR JU in November 2020 and was used and refined successfully during the course of 2021. This HR system is based on the Commission's HR management rules, in particular the staff regulations and the conditions of employment of other servants of the EU ([56]), the general implementing provisions thereto and the related business processes. The first phase of the implementation of SYSPER for Agencies was completed in November 2020 through the deployment of the initial modules:

- identity management,
- organisation management (organisation chart and job quotas),
- employee personal data management,
- time management (including work patterns, leave rights, absences and flexitime).

Training sessions were made available to staff throughout the organisation to support the deployment of these modules.

In 2021, the implementation of the job information system module began and will be implemented by the second quarter of 2022.

The Administrative Board did not adopt any decisions in relation to implementing rules.

On the other hand, the Governing Board of the SESAR 3 JU, at its first meeting on 14 December 2021, adopted the necessary HR decision to allow the Executive Director to continue running the SESAR 3 JU. Table 21 provides the list of HR decisions adopted by the Governing Board during that meeting. Several of these decisions needed to be transferred from the former SESAR JU entity to the SESAR 3 JU to immediately secure the required administrative arrangements.

Table 21: List of HR decisions adopted by the Governing Board on 14 December 2021

Reference	Subject
GB(D)09-2021	Establishment of voting rights
GB(D)10-2021	Criteria/Selection Scientific Advisory Board
GB(D)11-2021	SRIA
GB(D)12-2021	Transfer of assets, liabilities and unused appropriations identified by the Directorate-General for Budget
GB(D)13-2021	Adopting the transitional elements related to the SESAR 3 JU's annual work programme, budget, staff establishment plan and procurement plan for 2021 and 2022
GB(D)14-2021	Structure of the programme office
GB(D)15-2021	Delegation of appointing authority (AIPN) powers to the Executive Director
GB(D)16-2021	Rules of employment of trainees
GB(D)17-2021	Learning and development
GB(D)18-2021	Staff implementing rules/decisions

([56]) As last amended by Regulation (EU, Euratom) No 1023/2013 of the European Parliament and of the Council of 22 October 2013 amending the Staff Regulations of Officials of the European Union and the Conditions of Employment of Other Servants of the European Union (OJ L 287, 29.10.2013, p. 15).

Reference	Subject
GB(D)19-2021	Rules on SNEs

The staff establishment plan can be found in Annex II. Table 22 shows the results of benchmarking actual staff numbers at the end of 2020 against the staff establishment plan (including three additional SNEs).

Table 22: Benchmarking on HR

Job type (sub)category	Year N – 1 (%)	Year N (%)
Administrative support and coordination	***29.1 %***	***29.4 %***
Administrative support	15 %	16 %
Coordination	14 %	13 %
Operational	***61.2 %***	***62.1 %***
General operational	25 %	23 %
Programme management	24 %	25 %
Top-level operational coordination	10 %	10 %
Evaluation and impact assessment	3 %	3 %
Neutral	***9.6 %***	***8.5 %***
Finance	10 %	8 %
Control	0 %	0 %

3 Governance

The SESAR JU met all of its objectives related to strategic steering of the SESAR programme in 2020, as set out in Section III of the 2021–2023 SPD. This includes the following achievements and results.

- Ensure effective and efficient SESAR 2020 programme governance meetings. The SESAR JU held four meetings with the Scientific Committee, four meetings with the Programme Committee and one meeting with the Master Planning Committee. These three advisory bodies provided support to the SESAR JU Executive Director in steering the operational activities of the SESAR JU by providing a number of contributions in the form of strategic document reviews, participation in evaluation activities, etc. (see Sections III.4, III.5 and III.6).

The governance of the SESAR 2020 programme is depicted in Figure 17.

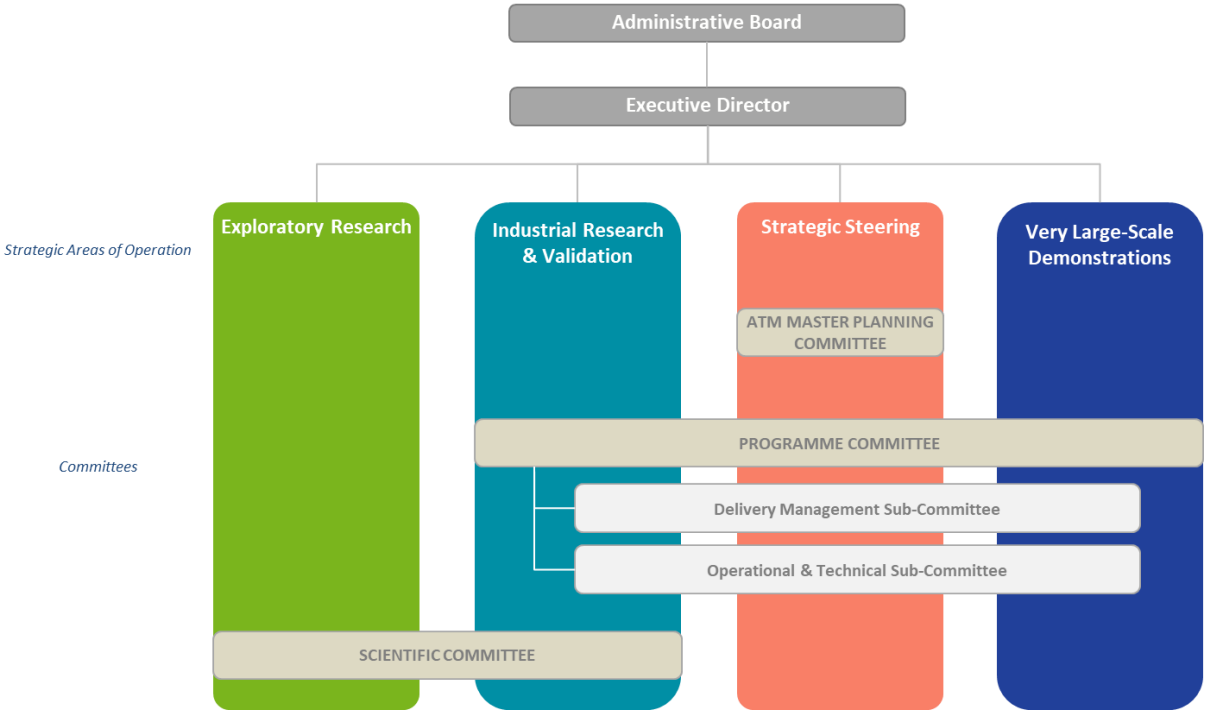


Figure 17: Governance of the SESAR 2020 programme

The following sections summarise the contribution of the Administrative Board (SESAR JU governance) and of the advisory bodies (the Scientific Committee, Programme Committee and ATM Master Planning Committee (MPC)) to the SESAR JU activities in 2021.

3.1 Executive Director: Changes in leadership

In July 2021, Florian Guillermet stepped down from his role as Executive Director of the SESAR JU to take up a new position as CEO of DSNA, France's ANSP. Guillermet took up the leadership of the SESAR JU in 2014. He oversaw the successful completion of the first SESAR R&I programme, as well as the roll-out of a second programme, winning industry-wide support and recognition for his strong and successful management of the partnership.

Following the departure of Florian Guillermet, the Administrative Board of the JU decided to appoint Richard Frizon as its Executive Director *ad interim,* to ensure the smooth and effective continuation of the work of the JU until the appointment of a new Executive Director in early 2022. Richard Frizon joined the SESAR JU in 2019 and, as Executive Director *ad interim*, he was tasked with managing the operations of the JU in accordance with its work programme, as well as ensuring the successful transition to and launch of the SESAR 3 JU at the end of 2021.

3.2 Activities of the Administrative Board in 2021

In 2021, the Administrative Board of the SESAR JU held three remote plenary meetings and adopted 22 decisions, 20 of which through written procedures (Table 23). The main focus of the Administrative Board was to follow up the achievement of the SESAR JU's work programme for 2021 (as described in Chapter I of this document), to oversee the process for the recruitment of the new Executive Director, to appoint the Executive Director *ad interim* and to ensure the preparation of the legal acts necessary for the transition to the SESAR 3 JU.

Table 23: Administrative Board decisions in 2021

Subject	Type of decision	Date of adoption
Approval of the draft 2022–2024 SPD	Written procedure	28 January 2021
Approval of the Internal Audit Capability annual audit plan for 2021	Written procedure	12 February 2021
Approval of the decision on Article 25 restrictions	Written procedure	17 February 2021
HR – updated organisation chart	Written procedure	12 February 2021
Adjustment of Dassault Aviation value of in-kind contribution to the SESAR JU	Written procedure	23 April 2021
Adjustment of SEAC value of in-kind contribution to the SESAR JU	Written procedure	23 April 2021
Adjustment of Thales LAS France SAS value of in-kind contribution to the SESAR JU	Written procedure	23 April 2021
Value of in-kind contributions and voting rights allocation	Written procedure	26 April 2021
Appointment of the vice-chairperson	ADB(M)052	6 May 2021
Adoption of the first amended 2021 SPD	Written procedure	25 May 2021
Approval of vacancy notice for the position of Executive Director	Written procedure	11 June 2021
2020 CAAR	Written procedure	21 June 2021
Opinion on the annual accounts for 2020	Written procedure	24 June 2021
Appointment of the Executive Director *ad interim*	Written procedure	1 July 2021
Permission to engage in post-employment activities	Written procedure	9 July 021
Adoption of the second amended 2021 SPD	Written procedure	23 September 2021
Appointment of the members of the selection panel for the position of SESAR JU Executive Director	ADB(M)054	7 October 2021
Amendment of the SESAR JU membership agreement	Written procedure	4 November 2021

Subject	Type of decision	Date of adoption
Transfer of assets and liabilities to the SESAR 3 JU	Written procedure	8 November 2021
2020 annual accounts and ECA report	Written procedure	19 November 2021
Appointment of the alternative representative of the SESAR JU's members other than the EU in the preselection panel for the position of SESAR JU Executive Director	Written procedure	16 November 2021
Approval of the 2022–2024 SPD	Written procedure	25 November 2021

3.3 Governing Board

The Governing Board (GB) of the SESAR 3 JU held its first meeting on 14 December 2021, at which more than 50 members and observers participated (either physically or online).

The members of the Governing Board are listed in Annex VIII. Article 3(2) and article 3(3) of the Rules of Procedures of the GB grant observers right to the chairperson and the vice-chairperson of the States' Representatives Group and to the chairperson of the Scientific Committee. According to article 3(4), the GB may invite, on a case-by-case basis, other persons to attend its meetings as observers (without voting rights).

Table 24 lists the decisions adopted by the Governing Board during that meeting. These decisions represent the legal acts necessary to allow the Executive Director to continue running the SESAR 3 JU until the programme elements are adopted. Several of these decisions needed to be transferred from the former SESAR JU entity to the SESAR 3 JU to immediately secure the required administrative arrangements.

Table 24: Decisions adopted by the Governing Board during its first meeting (14 December 2021)

Reference	Subject
GB(D)01-2021	Financial rules
GB(D)02-2021	Omnibus decision
GB(D)03-2021	Rules on confidentiality and conflicts of interest
GB(D)04-2021	Code of conduct of the Governing Board
GB(D)05-2021	Anti-fraud strategy
GB(D)06-2021	Internal rules for the SESAR 3 JU on Article 25 restrictions
GB(D)07-2021	Rules of procedure of the Governing Board
GB(D)08-2021	Internal control framework
GB(D)09-2021	Establishment of voting rights
GB(D)10-2021	Criteria/selection of the Scientific Advisory Board
GB(D)11-2021	SRIA
GB(D)12-2021	Transfer of assets, liabilities and unused appropriations identified by the Directorate-General for Budget
GB(D)13-2021	Adopting the transitional elements related to the SESAR 3 JU's annual work programme, budget, staff establishment plan and procurement plan for 2021 and 2022

Reference	Subject
GB(D)14-2021	Structure of the Programme Office
GB(D)15-2021	Delegation of AIPN powers to the Executive Director
GB(D)16-2021	Rules of employment of trainees
GB(D)17-2021	Learning and development
GB(D)18-2021	Staff implementing rules/decisions
GB(D)19-2021	Rules on SNEs

3.4 Contributions from the Scientific Committee in 2021

During the fifth and final year of its mandate, the SESAR 2020 Scientific Committee continued building on the experience achieved during the previous years, and expanded the mission and objectives of the committee into different directions while remaining engaged.

The Scientific Committee concentrated on finalising all task force activities and consolidating its recommendations in preparation for the end of the mandate and transition to different regulatory arrangements. A new Scientific Committee linked to the Governing Board of the SESAR 3 JU will be established in 2022.

3.4.1 Task forces

The most important achievements and conclusions of the task forces for 2021 are summarised below.

3.4.1.1 SESAR Digital Academy

Regarding the SESAR Digital Academy, the task force organised three separate, half-day workshops with representatives of relevant stakeholders. During 2021, representatives of universities (academics), students and industry were invited to a structured dialogue with the task force via separate light touch, online workshops. The events were very well attended and a rich discussion was established, delivering highly valuable insights. Specific needs, expectations and potential contributions per stakeholder group were identified and appropriate recommendations were developed to be assessed and considered during SESAR 3. Overall, the value of the SESAR Digital Academy was very well recognised and its evolution and maturation were well recognised by all stakeholders. The initial steps as developed and implemented by the Engage KTN were considered very valuable building blocks, which should be further developed. A continuation of and evolution in the course of the next institutional partnership on ATM is recommended.

3.4.1.2 Improved scientific methodology

Regarding the improved scientific methodology, the most important achievement of the task force was to organise a workshop dedicated to one of the recurrent themes of ATM research, the challenges of human-in-the loop simulations, and within that, to focus on how to make best use of a limited number of participants. Besides eliciting and summarising the best practices of such simulations in a recommendations paper, the most promising outcome of the workshop and a potential area for further interest was the field of remote simulations. The task force recommends that this initiative be investigated more thoroughly and that a research line be opened on this, particularly related to virtual ATM, distributed simulation and agent-based simulation, providing support for accessing and using fully connected remote simulation platforms.

3.4.1.3 Performance measurement

Regarding performance measurement, this task force was requested to provide recommendations in the area of target setting and management. This was designated ‘recommendations paper 2’, which was to be produced during SESAR 2020 (wave 2/3) and intended for use in the R&D programme in SESAR 3. The task force liaised with the SESAR JU and PJ19-04 throughout. Five packages of main recommendations were presented, concluding with general recommendations (next steps) regarding actions on the launch of SESAR 3:

1. ‘target setting’: nomenclature;
2. centralised, extended cost framework;
3. capturing KPAs without quantitative targets (ambitions);
4. supporting solution assessments and an open culture;
5. centralised, aggregate modelling approach.

Of the five main packages of recommendations put forward, packages 2 and 5 demonstrate the largest gap between current practice and what performance assessment might attain in SESAR 3. Other packages, such as 1 and 4, could be taken up with *relatively* little effort or adjustment to current practice. Package 3 is an intermediate case: the rate-limiting step here is likely to be assigning quantitative targets (ambitions) for those KPAs currently without them, but where they are needed.

Several elements of the recommendations are connected. For example, better assessing that solution X has a positive impact on KPI Y and a ‘negative’ impact on KPI Z (recommendation 4) would be supported by greater coverage across all KPAs (recommendation 3), which in turn would benefit from centralised modelling (recommendation 5).

Overall, several recommendations allocate more work into the call stage and more emphasis on pre-emptive and centralised modelling, to alleviate pressure from the solutions during the project execution phase. These changes could be implemented in a phased manner over the SESAR 3 calls; everything does not need to be achieved immediately on launch.

The SESAR 3 JUwill need to reflect a more mature performance assessment programme (drawing on previous experience and lessons learned) and, in particular, the need to adapt to an increasingly complex environment (e.g. drones, new entrants, increased service orientation, the evolution of environmental targets, regulations and indicators), resulting in a more complex framework. The need for independent review and expert support of solutions in the Digital European Sky programme, building on the success of PJ19-04, will be vital. Explicit next steps, to be considered relatively early on after the launch of the SESAR 3 JU, have been proposed.

3.4.1.4 Security Task Force

The Security Task Force has presented findings on the inclusion of security matters into the early stages of ATM R&D. Security-by-design is acknowledged by the stakeholders as an important requirement, otherwise the cost of security can increase very quickly. Any new ATM solution will need to take security into account from the very beginning. Another important point to recognise is that the ATM systems in the foreseeable future will need to be linked with the legacy systems that are lacking modern security protections.

The task force acknowledges that the scope and reach of the SESAR JU is limited to R&D activities. From both OPTICS2 deliverable D2.2 and discussions in workshops, it has become clear that a number of non-technological barriers (legal and organisational) exist that are preventing successful implementation of cybersecurity research results. Thus, the task force findings can be divided into two groups: the programme-level findings and the strategic findings. The programme-level findings

describe actions or strategies that could be applied in the future SESAR 3 JU partnership, as they lie within the remit of R&D. The strategic findings indicate avenues that the partnership could want to explore; these were listed in order to play an active role in promoting the uptake of cybersecurity issues through collaboration with the appropriate, external organisations.

3.4.1.4.1 Programme-level findings

Finding 1. The task force finds the security risk assessment methodology (SecRAM) approach to be an appropriate means to conduct a formal cybersecurity risk assessment for the current and future ATM R&D projects under the SESAR partnership. The output of the SecRAM may be to argue that the project does not raise any explicit cyber concerns, but such an argument needs to be reviewed by the project manager early in the project life cycle. The strong point of the SecRAM lies in the fact that it does not specify the exact vulnerabilities, but lists security requirements and the underlying security risk assessment. It should be noted that these requirements can be addressed in different ways in the final, deployable system. Furthermore, in the R&D V1–V3 phases, the security requirements and risk assessments are in a sufficiently high-level form that it should not preclude information-sharing between project members and the SESAR JU.

Finding 2. The task force finds that one of the paths for ensuring that cybersecurity matters are properly taken into account is their inclusion from the proposal stage of the future projects. One way of ensuring that sufficient attention is paid to cybersecurity could be the provision of high-level maturity risk assessment by applicants as an eligibility criteria for entities answering the calls for proposals in the next SESAR work programme. Another possibility would be to present evidence that project members have security training.

Finding 3. 2021 has seen an increased number of cyberattacks on research institutions. It might be worth exploring the costs and benefits of deploying a specific infrastructure for security information exchange for the future SESAR research programme, in view of these events. The task force members can provide links to relevant agencies within the Member States that now place this expectation on domestic research programmes, in the light of recent attacks on universities from nation states outside Europe.

Finding 4. The safety and security objectives often compete, but as they are equally important to ensure safe and secure air transport, they should be addressed jointly. For instance, existing intrusion detection tools have not been designed to meet the requirements of ED-143 ([57]). Thus, the task force considers the development of a joint safety/security approach to be of the utmost importance. The SecRAM only partially satisfies this requirement, and further extensions to the existing approach that align with the safety management systems of partner organisations could be included in research programmes to be funded.

Finding 5. Many cybersecurity issues are not unique to the air transport industry, and existing knowledge can be reused. ATM R&D would benefit from a strategy of investing in issues that can best be addressed through collaboration.

Finding 6. The task force acknowledges the strong and continued interest of stakeholders in participating in the cyber expert community. In SESAR 1, the security community existed and formulated the first SecRAM. Such a community is useful, as it enables the sharing of best practices and can strengthen the quality of security risk assessments and the security of the final ATM solutions, and could be fostered in the new SESAR partnership.

([57]) EUROCAE ED-143, 2008 edition (September 2008): Minimum operational performance standards for traffic alert and collision avoidance system II (TCAS II) version 7.1.

Finding 7. Novel technologies (e.g. AI and drones) offer promising opportunities in improving ATM. However, their introduction will also enlarge the attack surface with unknown vulnerabilities. To understand these novel vulnerabilities during the design process, SecRAM should be complemented by novel methods, such as computer-simulation-based cybersecurity penetration testing and the use of more sophisticated digital twins, which are in development by ECAC states.

3.4.1.4.2 Strategic findings indicating appropriate paths for external collaboration

Strategic finding 1. There is a need for closer links with other sectors' institutes and other national and European agencies to stop developing research in niche areas and to ensure better communication and cooperation between science, industry and policymakers across different domains. The future SESAR partnership could work on identifying potential areas of cybersecurity research that overlap with other domains, and coordinate with EUROCONTROL, EASA and EU cybersecurity research plans ([58]).

Strategic finding 2. There is a need for an improvement of regulatory and organisational processes for the exchange of security information across national borders, in many industrial areas, not only ATM. The future SESAR partnership could play an instrumental role in promoting the development of such regulation and organisational processes within Europe.

Strategic finding 3. There is a shortage of cybersecurity expertise (e.g. in looking at the socio-technical system as a whole). Investment in education is essential for growing cybersecurity maturity. Through the SESAR Digital Academy initiative, the future SESAR partnership could stimulate the identification and further development of the necessary adjustments of cybersecurity courses for the ATM sector in Europe.

3.4.2 Transversal activities

On top of the work performed by the different task forces, a number of transversal activities have been carried out. With the majority of the task forces having completed their work by May or June 2021, the second semester of the year was devoted to the review of the SRIA for ATM documents by all Scientific Committee members. The scope of the activity was the critical review of the SRIA to:

- identify future research directions not explicitly mentioned;
- detect challenge areas, mainly in the ER framework, where the existing text of the SRIA was considered not properly developed.

The activity spanned the period between June and September 2021, during which all Scientific Committee members engaged, individually or in groups, their scientific networks in a critical analysis of the SRIA text. This resulted in a recommendation paper to the SESAR JU Executive Director, organised by flagships (like the SRIA), to facilitate the possible inclusion of the research directions into pre-existing SESAR documents used for the preparation of the MAWP and, eventually, the technical specifications for SESAR 3 JU calls.

In addition, the committee supported activities related to the SESAR research and innovation programme, such as the evaluation of the applications for the Young Scientist Award, the evaluation of the papers for the annual SESAR Innovation Days event that took place virtually owing to the COVID-

([58]) The new developments in the area of cybersecurity within the EU should be followed and taken into account, such as Regulation (EU) 2021/887 of the European Parliament and of the Council of 20 May 2021 establishing the European Cybersecurity Industrial, Technology and Research Competence Centre and the Network of National Coordination Centres (OJ L 202, 8.6.2021, p. 1–31).

19 pandemic (see Section I4.2.3.1 for more information), and the review of some key SESAR documents, such as the performance framework in coordination with PJ19.04.

On one hand, the COVID-19 pandemic hindered the usual working arrangements and face-to-face meetings of the committee, also preventing the preparation of events, such as physical workshops, which have previously been used to make progress on some task force topics. On the other hand, it provided a strong push towards virtual events (i.e. webinars) under the SESAR Digital Academy umbrella, which have been widely recognised as extremely interesting and useful by the programme members.

Regarding the Engage KTN itself, continual reporting of the ongoing activities and achievements to the Scientific Committee members and the close link established with the SESAR Digital Academy Task Force members paved the way for a smooth transition and continuity of several tasks and initiatives, mindful of the expected Engage project closure in June 2022.

The continuous engagement with the SESAR JU communication media (e-news, LinkedIn and Twitter; see Section II.1.5) and the attendance at the meetings of external observers have contributed to boosting the visibility of the committee to all levels, both inside and outside the organisation, and have created a higher awareness of its scope and ongoing work. One example of this is the workshop with the SESAR JU Programme Committee members that was hosted by the Digital Academy Task Force and held in September 2021, which represented an opportunity to discuss the industry perspective on the definition of the recommendations to the SESAR JU Executive Director for the improvement of the current SESAR Digital Academy.

3.5 Contributions from the Programme Committee in 2021

Since its establishment in November 2016, the renewed Programme Committee has assisted the Executive Director in defining and executing effective programme management through strategic guidance and tactical steering of the SESAR JU's work programme, but with its remit limited to the higher maturity IR and VLD activities.

Four meetings were held in 2021, addressing the following main topics.

1. In close coordination with its members, the SESAR JU closely monitored the impact of the COVID-19 crisis on its projects and members. An in-depth analysis of the impact of the crisis on the development of the SESAR solutions was performed at the level of the Delivery Management Subcommittee throughout 2021, identifying potential issues and potential mitigating actions. Reports of the overall situation were regularly sent to the Programme Committee, highlightingthat the second and third waves of the COVID-19 pandemic produced additional difficulties for the projects. The SESAR JU members drew the Programme Committee's attention to greater than anticipated difficulties in implementing mitigation actions (e.g. the allocation of tasks to another contributor); in the case of airports, a refocus on core business, with a knock-on impact on R&I activities; and difficulties in accessing validation platforms and preparing validating exercises. Therefore, delays and their impact on programme output have significantly increased, due to the following reasons: simulation facilities not being available/sufficient to cope with all of the demands (i.e. delayed exercises lead to increases in demands) and, for some projects, 'buffers' for finalising the different outcomes and deliverables with the desired quality being consumed. As a result, the Programme Committee supported the SESAR JU's proposal to organise, with the Delivery Management Subcommittee, a coordinated approach aiming to extend the duration of some grants as a key mitigation action to secure the delivery of the SESAR solutions. This execrise was successfully conducted, leading to the signing at the end of 2021 of the grant amendments

for extending the duration of 13 wave 2 and wave 3 projects until the end of June 2023. A few additional extension requests will be addressed in 2022. The duration extension will allow the projects to reschedule their activities and will provide more time for executing the validation activities, finalising the technical deliverables and running the maturity gates.

2. The SESAR 2020 programme delivery approach is based on the release process, which identifies, on a yearly basis, the solutions that will be delivered at a specific maturity level and the planned VLDs. The Programme Committee supported the SESAR JU in the context of three releases outlined in Sections I.1.1.2 and I.4.3.3. Release 10 (execution from 2020 to April 2021) has delivered its results, and these were shared with the Programme Committee through the release 10 report (more information on the release 10 outcomes can be found in Section I.4.3.3.1). The release 11 plan, based on the information on validation activities provided in the wave 2 and wave 3 project schedules, was approved by the Programme Committee in December 2020. Regular progress reports on the validation of release 11 solutions were sent to members to ensure that execution remained in line with the plan (more information on the execution of release 11 can be found in Section I.4.3.3.2). The Programme Committee also endorsed, in December 2021, the release 12 plan, addressing all validation and demonstration activities from January to February 2023.
3. The Programme Committee members were also regularly updated about the progress of the R&I programme towards meeting the ATM Master Plan ambition. A Master Plan coverage report was made available, presenting a snapshot of the R&D status at that specific time. The report provided an overview of the current status of the programme delivery and the forecast at the end of SESAR 2020. With a focus on the key R&D needs to be addressed in master plan phases A, B and C, the SESAR JU reported in December 2021 that 80 % of the expected solutions were to be delivered at the V3/TRL6 level. The remaining 20 % that should reach V2/TRL4 at the end of SESAR 2020 have been included in the SESAR 3 programme and should be adressed by the first SESAR 3 JU IR call.
4. The Programme Committee meeting also offered the SESAR JU members the opportunity to present their views about their participation in the SESAR 2020 programme. They all underlined the importance of the cooperation between different stakeholders and the fundamental role of the partnership (bringing together AUs, ANSPs, airports, ground and airborne industry, and research institutions) in reaching successful results and paving the way for the future programme. A key message was that VLDs have been hugely successfully in addressing the industrialisation gap. It was also highlighted that the partnership has adapted to the new exceptional situation and continued working very well: members have learnt to do things differently and overall in a more efficient and economical way. The working arrangements put in place during the COVID-19 crisis to be able to work in a virtual way are very valuable and should be taken forward.

3.6 Contributions from the Master Planning Committee in 2021

Since its establishment in January 2017, the MPC has assisted the Executive Director with strategic advice on the maintenance, execution and update of the European ATM Master Plan, and helped to maintain a strong connection between SESAR development and deployment activities.

The MPC held only one meeting in 2021, on 28 October. During the first half of the year, the MPC meeting was initially planned on 25 June 2021, but the decision to postpone it was taken due to the priority given to all of the preparations for the future SESAR 3 JU, which represented a huge workload.

The 13th MPC meeting, held at the end of October, was the last MPC meeting under the SESAR JU governance arrangements.

This meeting was devoted mainly to the action plan aiming to strengthen and simplify the master planning process to safeguard the strategic value of the European ATM master plan, which is considered an important and useful instrument.

The proposed action plan aims to further improve the master planning process. The SESAR JU presented the action plan, composed of three improvement packages ([59]), while pointing out that achieving the expected improvement to the master planning process in full requires successful implementation of this action plan as a whole. Within the scope of the action plan, a clear set of goals, actions and success criteria are set for each of the three improvement packages, including the time frame and the resources required. The action plan focuses on strategic planning and monitoring (without operational and technical details) to generate more buy-in from decision-makers, including Member States, in the master planning process. It should also address the link to the performance scheme.

MPC members supported the action plan, including both of the updates ([60]) proposed by the representative of the European Commission (Directorate-General for Mobility and Transport), without raising concerns, and they stressed the need for the master planning process to better cover the industrialisation phase and its associated requirements.

MPC members received the approved action plan on 26 November 2021. Thus, they can move forward with the gradual implementation of the action plan under the oversight of the future SESAR 3 JU Governing Board, in which all stakeholders will be represented.

Finally, at the MPC meeting, the SESAR JU noted the main achievements of the MPC to date and warmly thanked all of the MPC members since 2017 for the work they have accomplished. The SESAR JU noted that all of the MPC members could be proud of this success story and all of the participants congratulated each other mutually.

([59]) Improvement package 1, 'Define future JU process and associated controls'; improvement package 2, 'Improve monitoring of the execution of the Master Plan; and improvement package 3, 'Further increase connection of the Master Plan with EU policy priorities and initiatives'."

([60]) The first update was that the notion of 'unified planning' should be pursued, although within the boundaries of the EU regulatory obligations and tasks of each entity. The second update was that the implementation horizon of improvement package 2 was postponed from 2022 to 2023; it was stressed that 2022 should be considered a trial year in which each entity concerned will endeavour to do its best to achieve maximum progress and help identify any potential bottlenecks (e.g. in the availability of data) to de-risk the achievement of the objective by 2023.

4 Internal control framework

The SESAR JU met all of its objectives related to effective financial, administrative and corporate management in this domain, as set out in Section III of the 2021–2023 SPD. This includes the following achievements and results.

- Monitoring the efficiency and effectiveness of the SESAR JU's project audit activities. Project audit activities were carried out in accordance with the plan.
- Monitoring the efficiency and effectiveness of the SESAR JU's corporate and management activities. Actions in relation to compliance requirements were taken in accordance with the plan.
- Monitoring the exception and non-compliance events register (target within 1 %). In accordance with the policy and process described in paragraph IV.15.4., in 2021, the SESAR JU recorded: one non-compliance event resulting of the non-activation of the H2020 Guarantee Fund and/or issue a Recovery Order due to the bankruptcy of a beneficiary (H2020 project 763702 (PercEvite) –) and one exception linked to the extension of duration of the contract governing the monitoring and maintenance of the SESAR JU premises' alarm system (CTR SJU/LC/327-CTR).

4.1 Financial procedures

The SESAR JU financial rules are aligned with Commission Delegated Regulation 2019/715 on the framework financial regulation for the bodies set up under the Treaty on the Functioning of the European Union and the Euratom Treaty and referred to in Article 70 of Regulation (EU, Euratom) 2018/1046 of the European Parliament and of the Council.

In line with Article 112(2) of the framework financial regulation, the SESAR JU revised its financial rules. The revision process was concluded in October 2019 by the adoption of the new financial rules by the Administrative Board, as described in Section II.2.

The SESAR JU adopted, in September 2021, its manual of financial circuits relating to the JU budget implementation. The manual establishes the financial circuits within the SESAR JU, which allow the correct legal and regular implementation of the budget for the revenue by recovery orders and forecasts of revenue, and for the expenditure from the budgetary commitment until the payment of the expenditure to the de-commitment and possible recovery orders.

4.2 *Ex ante* controls on operational expenditure

The SESAR JU financial rules, Article 44(5), state:

> *In order to prevent errors and irregularities before the authorization of operations and to mitigate risks of non-achievement of objectives, each operation shall be subject at least to an ex ante control relating to the operational and financial aspects of the operation, on the basis of a control strategy which takes risk and cost-effectiveness into account.*

A key element of the *ex ante* controls applicable to H2020 grants of the SESAR JU is the related guidance issued by the Commission and applicable to all H2020 stakeholders.

4.3 *Ex post* control of operational expenditure and error rates identified

Since 2007, the R&I family has adopted a common audit strategy intended to ensure the legality and regularity of expenditure on a multiannual basis, including the detection and correction of systematic errors.

For H2020, the CAS of the Common Implementation Centre undertakes all audits, including those concerning the executive agencies and the joint undertakings. This is a major step towards ensuring a harmonised approach and minimising the audit burden on beneficiaries.

The main indicators of legality and regularity of the EU framework programmes for R&I are:

- **the representative detected error rate**, based on errors detected by *ex post* audits on a common representative sample of cost claims across the R&I family;
- **the cumulative residual error rate**, which is the extrapolated level of error after corrective measures have been implemented by the Commission services following the audits, accumulated on a multiannual basis.

The target set for this control system for H2020 is to obtain a cumulative residual error rate within a range of 2–5 %, aiming to be as close as possible to 2 % without necessarily expecting it to be lower than 2 %.

Progress against H2020 targets is assessed annually based on the results of the implementation of the *ex post* audit strategy and taking into account the frequency and importance of the detected errors along with cost–benefit considerations regarding the effort and resources needed to detect and correct the errors.

It should be noted, however, that, due to its multiannual nature, the effectiveness of the control strategy of the R&I family can be measured and assessed fully only in the final stages of the EU framework programme for R&I, once the *ex post* control strategy has been fully implemented and systematic errors have been detected and corrected.

Owing to the COVID-19 pandemic and related travel limitations during 2021, the CAS – in line with the instructions of the Commission – could not carry out the necessary on-the-spot missions and had to postpone some of them. To minimise the impact of COVID-19 on the implementation of the audit campaign, the CAS converted as many traditional audit assignments as possible into desk audits, in line with international best practices and auditing standards.

Despite restrictions and other objective challenges due to the COVID-19 pandemic, the foreseen audit target was achieved. The CAS managed to finalise audits on 514 participations, corresponding to 104.3 % of the planned most probable scenario for the 2021 target ([61]).

Table 25 presents the error rates calculated for H2020 at the end of 2021.

Table 25: Error rates calculated for H2020 (end of 2021)

Error rate	H2020 *ex post* audit result

([61]) Given the COVID-19 pandemic and related restrictions, the CAS developed several scenarios for the closure of audit targets.

Representative detected error rate	2.29 %
Cumulative residual error rate	1.67 %

4.3.1 Results of the Horizon 2020 *ex post* audits

In 2020, the Commission refined its methodology for calculating the H2020 error rates in line with the ECA's observations in its 2018 and 2019 annual reports ([62]). The methodology applied is described in Annex VI. As of January 2020, the Directorate-General for Research and Innovation applied the revised methodology on a sample of 1 304 audit conclusions. This resulted in the following error rates for H2020 ([63]) on 31 December 2021:

- representative detected error rate: **2.29 %** ([64]),
- cumulative residual error rate for the R&I family: **1.67 %**.

In line with the financial statement ([65]) accompanying the Commission's proposal for the H2020 regulation, a reservation is not necessary for the related expenditure if the cumulative residual error rate for the programme falls within the target range of 2–5 %. In 2021, and despite the abovementioned caveats, the cumulative residual error rate for H2020, calculated at 1.67 %, more than fulfils this condition and is below the materiality threshold. Despite the absence of reservation, the root causes of errors have been identified, and targeted actions have been taken to address any identified weaknesses.

As H2020 is a multiannual programme, the error rates, and the residual error rate in particular, should be considered within a time perspective. Specifically, the cleansing effect of audits will tend to increase the difference between the representative detected error rate and the cumulative residual error rate, with the latter finishing at a lower value.

These error rates are calculated on the basis of the audit results available when drafting the annual activity report. They should be treated with caution, as they may change subject to the availability of additional data from audit results.

The decrease in the error rates in 2021 could be due, among other reasons, to the beneficiaries' increased knowledge of the eligibility rules and the inherent learning curve, as well as to the results of the communication campaigns, targeted webinars and training, addressed in particular to newcomers and SMEs.

([62]) When calculating the multiannual error rate, the Commission took into account the results of the audit reperformed by the ECA as part of module 2 of the (statement of assurance DAS for 2018–2019.

([63]) The H2020 audit campaign started in 2016. At this stage, four common representative samples with a total of 629 expected results had been selected. By the end of 2021, cost claims amounting to EUR 31.8 billion had been submitted by the beneficiaries to the services. In addition to the common representative samples, common risk samples and additional samples have also been selected. The audits of 3 424 participations were finalised by 31 December 2021 (of which 514 were in 2021).

([64]) Based on the 418 representative results out of the 629 expected in the four common representative samples.

([65]) The legislative financial statement accompanying the Commission's proposal for the H2020 regulation states: 'The Commission considers therefore that, for research spending under Horizon 2020, a risk of error, on an annual basis, within a range between 2–5 % is a realistic objective taking into account the costs of controls, the simplification measures proposed to reduce the complexity of rules and the related inherent risk associated to the reimbursement of costs of the research projects. The ultimate aim for the residual level of error at the closure of the programmes after the financial impact of all audits, corrections and recovery measures will have been taken into account is to achieve a level as close as possible to 2 %.'

4.3.2 Results of the *ex post* SESAR-specific audits

Even though the common representative sample is a basic indicator for the legality and regularity of the transactions for the entire research family, SESAR calculates its specific results based on audits of its own population and its own expenditure.

In 2020, two snapshots of the population of the SESAR activities (IR-VLD) were taken, on 30 June and 14 September. The amounts that had been paid by these cut-off dates (a total of EUR 93 million) resulted in a sample of 14 participations in 12 beneficiaries and an audit coverage of 16 %. This sample was supplemented by one additional participation as a top-up to the above population.

In addition, in the third common representative sample drawn by the CAS, two SESAR participations were included in two beneficiaries with one top-up.

The CAS finalised audit reports until 31 December 2021, covered 10 participations in seven beneficiaries (out of a total of 18 participations in 14 beneficiaries) ([66]) and resulted in a detected error rate of 0.67 %, with no systematic error found, and a residual error rate of 0.57 %. The SESAR cumulative residual error rate for the entire programme (2016–2021) was 1.30 %.

The error rates reported for 2021, annual and cumulative, stayed well below the target threshold of 2–5 %.

In 2021, one snapshot of the population was taken, on 18 June. The audit of the cost claims received and paid by this cut-off date resulted in a sample of nine participations in five beneficiaries. The results of this audit will be available in 2022.

4.3.3 Results of the *ex post* audits in assigned revenues

4.3.3.1 Geo-fencing

Following the processing of the final payment in 2020, and based on the analytic cost statements that were received, the SESAR JU drew an audit sample. The cost claim of Thales AVS (EUR 439 000) was selected, with the highest amount representing 60 % of total costs.

The audit took place in early January 2022. The audit of these funds was planned to be executed jointly by the SESAR JU and the external audit sector of the Directorate-General for Mobility and Transport (as agreed in Permanent Audit Panel meeting 035-2016); however, due to *force majeure* it was executed remotely by SESAR in-house auditors.

By 15 February 2022, the draft report had been prepared; however, the results are considered final, as they were agreed with the beneficiary during the closing meeting and the adjustments required are minor.

Based on the draft report, the audit resulted in a minor negative adjustment of EUR 12 000 in other direct costs. This error was not systematic. An additional adjustment was necessary in the indirect costs calculated as a consequence of the adjustment in other direct costs.

The error rate was calculated at 2.86 %, which is within the materiality threshold range of 2–5 % established by the European Commission to provide reasonable assurance on the expenditure.

([66]) In accordance with the revised targets as agreed in the CAS annual activity report for 2021 due to the consequences of the COVID-19 pandemic.

4.3.3.2 U-space

The final payment was made in 2020 and, based on the analytic cost statements that were received, SESAR drew the audit sample. The cost claims with the highest amounts per project were selected, so that at least 25 % of total costs per project were audited. The final selection resulted in 30 % coverage of total costs, consisting of nine audits in eight beneficiaries.

The audit was performed by Baker Tilly during 2021 and, by 15 February 2022, eight of the nine audits had been finalised and the remaining one was in the contradictory procedure.

Based on the final reports (and in the preliminary report in one case) on nine samples of U-space projects, the audits resulted in a very high error rate of 34 % (which is uncommon in comparison with the error rate calculated for the seventh framework programme (FP7) or H2020).

The error rate is far above the materiality threshold range of 2–5 % established by the European Commission to provide reasonable assurance on the expenditure; therefore, a reservation by the authorising officer is necessary (see Section V.3).

The SESAR 3 JU performed an analysis of the audit adjustments in order to identify the reasons.

- There is little evidence that the errors were caused by the fact that U-space is an assigned revenue with a different set of rules (CEF funds), legal requirements and eligibility criteria than the ones that SESAR has been working with throughout the years (FP7/H2020) and is managed outside the automated IT systems.

- The majority of the beneficiaries involved in these projects were newcomers, SMEs and start-ups with no previous experience in managing SESAR/EU funds. Therefore, they lacked adequate internal controls, proper time recording systems or best value-for-money practices.

- Despite the fact that clear guidelines were given during the implementation of the projects regarding the eligibility of certain costs, beneficiaries still made errors, either because they lacked a thorough understanding of the rules or because they did not respect them.

Given the results of the audit, corrective action will be taken by implementing the audit adjustments and making the relevant recoveries of funds.

Previous experience in the SESAR 2020 and innovation programme (FP7 and H2020) has shown that higher error rates in the core SESAR activities stem from the same typology of beneficiaries (newcomers and SMEs). For this reason, the SESAR 3 JU defined some actions aimed at reducing the error rate of H2020, Horizon Europe and any subsequent EU framework programme / assigned revenue:

- enhanced training will be provided to members / future beneficiaries through the European Commission communication campaigns (information sessions on Horizon Europe, etc.);
- a specific SESAR financial coordination group will be organised, to which members / beneficiaries' finance advisors will be invited, with the aim of explaining the financial provisions and answering questions;
- a financial information session will be included in every project kick-off meeting;
- dedicated information sessions will be held for newcomers, SMEs and beneficiaries that have not been audited by the European Commission services before – during these sessions, the consequences of not respecting the rules need to be underlined;
- SESAR will identify risk-prone beneficiaries at the grant agreement preparation phase (based on the *ex ante* risk-based assessment document that has recently been developed) and on-request material/training/advice will be offered;

- during the *ex ante* controls – and to the extent permitted by Horizon Europe – clarifications will be requested from risk-prone beneficiaries before the payment;
- the European Commission services are developing an AI tool that will be able to identify the riskiest beneficiaries per service.

4.4 European Court of Auditors

On 12 November 2021, the ECA published the final report on the annual audit of the SESAR JU accounts for the financial year 2020. The report concluded the following:

- the SESAR JU accounts present fairly, in all material respects, the financial position of the SESAR JU, the results of its operations, its cash flows and the changes in net assets for 2020, in accordance with its financial regulation and with accounting rules adopted by the Commission's accounting officer;
- the revenue underlying the accounts for 2020 is legal and regular in all material respects;
- the payments underlying the accounts for 2020 are legal and regular in all material respects.

In the report, the ECA also observed that EUR 6 million in funds under the U-space delegation agreement had not been entered into the 2020 budget by means of an amending budget or considered when planning actual needs for budget line 3700. The item has now been addressed by the SESAR JU. Furthermore, the ECA highlighted the fact that the SESAR JU has set up reliable *ex ante* control procedures and has implemented the Commission's internal control framework, which is based on 17 internal control principles and the representative and residual error rates of H2020 projects. Finally, the ECA concluded that the detailed audits of sampled H2020 payments made at the level of the final beneficiaries showed no reportable errors or control weaknesses. The report also included a follow-up of previous years' observations.

The full report including the reply from the SESAR JU can be found on the ECA website.

4.5 Internal Audit Service

Over the course of 2021, the IAS performed an audit on HR management and ethics in the SESAR JU. The fieldwork took place remotely and the final report was issued on 9 November 2021.

The auditors concluded that the SESAR JU's management and control systems that were put in place for HR management and the promotion of the ethical environment are overall adequately designed, efficient and effectively implemented and support the JU in achieving its business objectives. While the audit did not result in the identification of any critical or very important issues, the IAS considers that there are a few weaknesses and there is some room for further improvement in certain areas, such as workload management, the recruitment process and annual declarations of interest, individual objective setting, and communication on HR matters.

The auditors issued five recommendations rated 'important' (Table 26). There were no 'critical' or 'very important' recommendations.

Table 26: Recommendations from the IAS audit on HR management and ethics in the SESAR JU (report published 9 November 2021)

Recommendation	Criticality	Current status

Recommendation 1: improve the workload management process	Important	Action plan under implementation
Recommendation 2: improve the controls in the management of the recruitment process	Important	Action plan under implementation
Recommendation 3: improve the management of the appraisal and reclassification processes	Important	Action plan under implementation
Recommendation 4: improve the management of the ethics-related processes, namely that of the declarations of interest, the confidential counsellors network and the administrative inquiries	Important	Action plan under implementation
Recommendation 5: develop an internal communication strategy with relevance to HR processes	Important	Action plan under implementation

In order to address these recommendations and underlying risks, the SESAR JU set up a detailed action plan, which the IAS confirmed is suitable. The SESAR JU expects to implement all actions by the year-end of 2022.

4.6 Internal Audit Capability

In 2021, the Internal Audit Capability (IAC) performed activities in accordance with the 2021 IAC annual audit plan, which was approved by the SESAR JU Administrative Board (ADB(D)01-2021). These activities focused on assurance audits and consulting engagements.

In this context, ad hoc advice on efficient and effective management and ethics was provided on a regular basis. The IAC twice performed a compliance review related to all payments executed by the authorising officer by delegation (AOD) and the authorising officer by subdelegation (AOSD) and contributed to the validation of ABAC user authorisations. The IAC also organised two sessions for staff on awareness raising on ethics and anti-fraud measures, and produced an anti-fraud-related newsletter addressed to all staff (see Section IV.12).

Furthermore, the IAC liaised with the IAS, the ECA and other relevant audit actors, monitored the implementation of several SESAR JU action plans related to past audits, and followed up on the discharge procedure regarding the 2018 and 2019 SESAR JU accounts. The IAC also coordinated the audit on HR and ethics performed by the IAS and provided written replies to the ECA in the context of the annual audit of the 2020 accounts.

The IAC was also a member of the SESAR JU COVID-19 crisis cell and was involved in the preparations for the SESAR 3 JU. In this context, the IAC prepared rules on confidentiality, prevention, avoidance and the management of conflict of interest of the SESAR 3 JU and a code of conduct for the Governing Board.

The IAC chaired the Permanent Audit Panel and reported to the SESAR JU Administrative Board on risks, audits and the implementation of recommendations. In addition, a detailed annual report on IAC and general audit activities in 2021 will be provided to the SESAR JU Administrative Board in Q2 2022.

4.7 Follow-up of recommendations and action plans for audits and evaluations

Over the course of 2020, the IAS performed an audit on H2020 grant implementation in the SESAR JU. The fieldwork took place remotely and the final report was issued on 8 December 2020.

In this context, four audit recommendations with a criticality level of 'important' were issued. The SESAR JU set up an action plan to address these recommendations and implemented the related actions over the course of 2021. By December 2021, the SESAR JU had submitted the four recommendations for closure. Consequently, the IAS performed a follow-up audit of open recommendations to assess the progress made in implementing these. Based on the results of this follow-up audit, the IAS concluded that the four recommendations had been adequately and effectively implemented by the SESAR 3 JU and, on 31 January 2022, the IAS informed the SESAR 3 JU of the fact that all recommendations stemming from the audit on H2020 grant implementation were formally closed.

As a result, all IAS and ECA recommendations stemming from before 2021 have been implemented and are now formally closed.

4.8 Follow-up of recommendations issued following investigation by the European Anti-Fraud Office

The SESAR JU was not subject to an investigation led by the European Anti-Fraud Office (OLAF) in 2020.

In November 2020, the SESAR JU was informed by the CAS that a red flag had been raised during an *ex post* audit of a SESAR JU project, indicating suspicion that fraud may have been committed by a SESAR JU beneficiary. Meanwhile, the suspicion has not been confirmed and no OLAF case was triggered as far as the SESAR 3 JU knows.

In accordance with the SESAR JU anti-fraud strategy ([67]), the SESAR JU uses the following indicators to report on OLAF cases:

- the number of files sent to OLAF for investigation – in 2021, no case of suspected fraud was reported to OLAF;
- the time elapsed between the receipt by staff or management of the first information on alleged internal fraud and the transmission of this information to OLAF (not applicable);
- the time elapsed between OLAF requests for information and the date when information is provided to OLAF (not applicable);
- the time elapsed between the receipt of an OLAF report and the decision on recovery or disciplinary sanctions by the SESAR JU (not applicable).

No follow-up actions to implement OLAF recommendations from previous years were required in 2021.

([67]) SESAR JU Administrative Board decision No ADB(D)04-2020, signed on 12 March 2020, on the updated 2020–2022 anti-fraud strategy.

4.9 Follow-up of observations from the discharge authority

4.9.1 Discharge in the 2019 financial year

In April 2021, the European Parliament granted discharge to the SESAR JU in respect of the implementation of the budget for the financial year 2019 and approved the closure of the accounts of the SESAR JU for the financial year 2019 ([68]).

In its resolution, the European Parliament made observations regarding budget and financial management, performance, procurement and recruitment procedures, internal control, and internal audits.

The observations of the European Parliament were formally acknowledged by the SESAR JU in Q3 2021. The SESAR JU replied in writing to the European Parliament, outlining the measures that the SESAR JU intends to adopt to address the observations made by the European Parliament.

The majority of the replies to the European Parliament consisted of further clarifications or details regarding the context of observations. Notably, the SESAR JU informed the European Parliament of the fact that all excess in cash contributions for the SESAR 1 programme were reimbursed to the appropriate SESAR JU members. The SESAR JU also informed the European Parliament about the content of the SESAR JU communication strategy and the wide range of channels that the SESAR JU uses to communicate its activities and encourage market uptake. In addition, the SESAR JU addressed aspects of intellectual property rights, KPIs included in the CAAR, risk management and the publication of information on the SESAR JU website. Finally, the European Parliament was informed of the fact that relevant indicators for all internal control principles and related characteristics had been developed by the SESAR JU.

4.9.2 Discharge in the 2020 financial year

In 2021, the SESAR JU supported the European Parliament in the discharge to the SESAR JU in respect of the implementation of the budget for the 2020 financial year. This procedure will be completed in Q2 2022.

4.10 Risk management

Risk management aims to enable an organisation to fulfil its mission and objectives in the most efficient and effective way by ensuring the timely and adequate identification, assessment (analysis and evaluation), management (treatment and escalation, as required), monitoring and controlling of risks and opportunities.

In 2021, one formal risk management workshop took place in June. The risk management team reviewed the four categories of risks identified in the SESAR JU's risk management policy, namely strategic risks, internal risks, Master Plan risks and programme risks, with a focus on critical risks affecting the achievement of the SESAR 3 JU objectives. A risk should be considered significant if its impact falls within at least one of the following categories:

- it jeopardises the achievement of strategic goals or the effective implementation of the mandate of the SESAR JU;

([68]) See the European Parliament's 2019 discharge for the SESAR JU.

- it causes serious damage to the SESAR JU's stakeholders or partners;
- it results in critical intervention at political level (e.g. European Council/Parliament) regarding the SESAR JU's performance;
- it results in the infringement of laws or regulations;
- it results in significant material and/or financial loss;
- it jeopardises the safety of staff;
- it seriously damages the SESAR JU's image and reputation.

Following the workshop, and in consideration of the above, the risks and the related actions outlined in the risk management policy were updated, and an additional risk related to the establishment of the SESAR 3 JU was identified and documented. A dedicated action plan was defined.

As a result of these activities, the SESAR JU updated its corporate risk register and froze it on 4 June 2021. The updated information on risk management was incorporated in the 2022–2024 SPD.

Furthermore, as explained in Section I.3.2, a dedicated transition group was set up to de-risk the transition to the SESAR 3 JU and to secure continuity of operations (as a response to the abovementioned risk). As this transition group was active until the end of 2021, and had the participation of all members of the Corporate Management Team, and for the sake of efficiency, there was no need to organise a second separate risk management workshop as formally suggested in the risk management policy. The risk register and its associated action planning was maintained during the transition planning and execution, meaning some risks were removed once the transition to the SESAR 3 JU was completed.

The status of risk management presented in Table 27 is the status of the SESAR JU corporate risk register at the end of 2021 and the related actions.

Table 27: SESAR JU corporate risks and response plan summary at the end of 2021

Reference	Risk description	Criticality	SESAR JU 2021 objectives (at the end of 2020) likely to be affected	Risk owner	Mitigation actions
CORP08	The COVID-19 crisis brings different types of challenges to the SESAR JU	Moderate	0.0. All objectives 6.8. Efficient and effective SESAR JU financial activities 3.4. Prepare release 12 3.7. Delivery of results of IR wave 3 projects 6.6. Efficient and effective SESAR JU HR activities	SESAR JU	
	1. Members' ability to support the established programme delivery is adversely affected by the financial/resource situation of the aviation sector: • the technical contributions of one member or several members of the SESAR 2020 programme may be lower than provided for in the SESAR JU membership agreement; • this situation would have an impact on the final outcome of SESAR 2020 projects, the delivery of SESAR solutions and the progress made in achieving the Master Plan				1a. Analyse the impact of the crisis and adapt as required to minimise disruption to the delivery of the SESAR programme 1b. Optimise the use of available funds through the transfer of unused budget between calls 1c. Establish support contracts with aviation stakeholders 1d. Adapt terms of payments for 2020 and 2021 to reduce the cash pressure on SESAR JU members and beneficiaries (cash to be recovered in future years in accordance with actual in-kind contributions) 1e. Increase pre-financing level for grants
	2. Members' financial contributions, including to the SESAR JU's running costs, are reduced: • the financial contribution of members other than the EU to the SESAR JU's running costs is defined in the membership agreement as a percentage of their in-kind contribution; • the financial contributions of one member or several members other than the EU may be lower than provided for in the membership agreement if in-kind contributions fall;				2a. Revise/optimise the SESAR JU's running costs budget 2b. Closely monitor members' in-kind payments and their contribution to the expected running costs of the JU to determine if staff reduction and/or termination of contracts with service providers will be necessary 2c. Maintain a reserve in the SESAR JU budget

	• as the contributions of members other than the EU cover a significant proportion of the agency's running costs (60 %), a decrease in the contribution to the running costs may result in the SESAR JU being unable fulfil some of its contractual obligations				2d. Monitor the effective contribution of non-EU members
	3. Restrictions imposed by the Belgian authorities and/or the European Commission affect the internal functioning of the SESAR JU. Restrictions on travel and access to the office and mandatory teleworking lead to inefficiencies, misunderstandings and errors and have a psychological impact on staff				3a. Carry out full-scale ICT testing of teleworking arrangements 3b. Trigger the business continuity measures and establish a crisis management cell to prepare strategies and plans 3c. Survey staff regularly to monitor how they adapt to the new working measures 3d. Coordinate regularly with the Staff Committee 3e. Monitor the ICT infrastructure needed to support general teleworking arrangements, including mixed teleworking and working from premises modes 3f. Acquire new IT tools, formalise new contracts and/or agreements with the European Commission, and implement revised procedures, supported by digital solutions (e.g. electronic workflows), to authorise legal and financial transactions 3g. Develop a strategy for returning to the office and provide clear guidance to staff about maintaining a safe working environment 3h. Organise coaching sessions for staff to help them adapt to the teleworking measures

CORP12	A letter has been received announcing the withdrawal from October 2022 of the Directorate-General for Budget accounting shared service that is used by the SESAR 3 JU. Given the lack of available and skilled staff resources, this action puts at risk the continuity and quality of the accounting function	High	6.8. Efficient and effective SESAR JU financial activities	SESAR JU	Look for synergies with other affected joint undertakings and define a satisfactory alternative to the Directorate-General for Budget centralised back-office service

4.11 Internal control and quality management

In 2021, in continuation of the activities of previous years, the SESAR JU continuously reviewed and improved its quality management system (QMS) in response to the SESAR JU's evolving business needs and to improve efficiency (see also Section IV.13).

4.11.1 Definition of indicators for the assessment of the internal control system

Upgrades in 2021 included the definition of indicators for the assessment of the internal control system implementing the SESAR 3 JU's internal control strategy. The internal control strategy clarifies how the QMS will be used to implement the European Commission internal control framework and has been summarised in the SESAR 3 JU's annual work programme documents (in the SPD until 2021). Following an observation of the ECA during the preliminary phase (fieldwork) of the audit on the SESAR JU's 2020 accounts (see Section IV.7), for the annual self-assessment and monitoring of the effectiveness of the control activities required by the internal control framework, the JU developed relevant indicators for all internal control principles and related characteristics. These indicators were submitted for approval to the corporate management team at the end of 2020, and will be used in CAARs from 2021 onwards.

4.11.2 Effectiveness of internal control systems

In previous years, the assessment of the effectiveness of internal control was based on an assessment grid, which has been replaced by the indicators mentioned in Section IV.11.1.

The SESAR 3 JU used these indicators for the first time in February 2022 to run the assessment for 2021. The result of this assessment is available in Annex IV.

4.11.3 Conclusions of assessment of internal control systems

The SESAR 3 JU management considers its internal control systems to be effective, and they will be maintained under continuous improvement.

4.12 Conflict of interest, fraud prevention and detection

The SESAR JU financial rules state that, for the purposes of the implementation of the budget of the SESAR JU, the SESAR JU shall apply internal control at all levels of management designed to provide reasonable assurance of achieving, inter alia, the objectives of prevention, detection, correction and the follow-up of fraud and irregularities ([69]).

To this end, the SESAR JU Administrative Board adopted the first SESAR JU anti-fraud strategy ([70]) in 2016. This first SESAR JU anti-fraud strategy addressed 2016–2019 and had a strong focus on risks related to the SESAR 1 programme. Therefore, an update of this first SESAR JU anti-fraud strategy was required. This update was drafted over the course of December 2019 and January 2020. The updated version builds on the anti-fraud actions performed by the SESAR JU from 2016 to 2019 and sets out a

([69]) SESAR JU Administrative Board decision No ADB(D)21-2019 adopted on 9 October 2019 on the financial rules (Article 29 and in particular Articles 31, 38, 44, 47, 84 and 106).

([70]) SESAR JU Administrative Board decision No ADB(D)4-2016 signed on 18 March 2016 on the anti-fraud strategy for 2016–2019.

new set of objectives and actions to address current risks, including H2020-specific risks. The SESAR JU Administrative Board adopted the updated anti-fraud strategy in March 2020 ([71]).

The SESAR JU updated anti-fraud strategy includes the following elements:

- the background and context of the anti-fraud strategy, including how this strategy aligns with the European Commission and how it addresses the internal control principles;
- fraud definitions;
- the results of the anti-fraud risk assessment, which was carried out as a stand-alone exercise in November 2019 and underlies the strategy;
- an overview of the means and staff resources that the SESAR JU has at its disposal to tackle fraud and to mitigate identified risks, including an overview of policies and processes that the SESAR JU has enforced since 2008 in the area of conflicts of interest and anti-fraud;
- the three main objectives of the anti-fraud strategy:
    1. maintain a culture of integrity;
    2. build capacity through training and guidance;
    3. prevent and detect external fraud;
- an overview of the indicators that will be used to report on the anti-fraud strategy in the CAAR;
- a detailed action plan that outlines the specific actions that the SESAR JU will undertake from 2020 to 2022 to address the three objectives of the anti-fraud strategy.

In this context, an anti-fraud implementation report for 2021 was submitted to the Executive Director in Q1 2022. The report provides an overview of the anti-fraud activities that were carried out by the SESAR JU in 2021. It notably describes specific training sessions that were set up in the field of ethics and anti-fraud in Q4 2021. These training sessions covered the following topics: fraud definitions, red flags, reporting of serious irregularities, conflicts of interest, outside activities, gifts and favours, the Early Detection and Exclusion System database, double funding, and plagiarism.

A total of two sessions were organised and took place in the form of web conferences in view of the mandatory COVID-19 teleworking rules that were in place in Q4 2021.

The training sessions were mandatory for all staff, including European Commission staff members, EUROCONTROL staff members, SNEs, trainees, and temporary staff and contractors working in the SESAR JU offices.

In terms of conflicts of interest, in December 2021, the SESAR 3 JU Governing Board adopted new rules on confidentiality, prevention, avoidance and the management of conflicts of interest of the SESAR 3 JU (GB(D)03-2021). These rules replaced the previous set of rules that had been applicable since 2008 ([72]). In addition, in December 2021, a code of conduct for the Governing Board was equally adopted (GB(D)4-2021).

([71]) SESAR JU Administrative Board decision No ADB(D)04-2020, signed on 12 March 2020, referring to the updated 2020–2022 anti-fraud strategy.

([72]) SESAR JU Administrative Board decision Nos ADB(D)10-2008 and ADB(D)03-2012 on confidentiality, independence and the management of conflict of interest of the bodies of the SESAR JU.

4.13 Strategy for efficiency gains

To cope with the complexity stemming from the management of its activities, the SESAR JU continued to strive for further efficiency gains, building on efficiency measures already implemented in the context of the SESAR JU from 2008 to 2021.

This was particularly important in 2021 considering the identified risk in terms of resources induced by the COVID-19 crisis and by the transition to the SESAR 3 JU, both of which are factors of major risk CORP05: 'The SESAR JU may not be able to take up new challenges due to limited human resources' (see Annex VIII of the SESAR JU's 2020–2022 SPD).

In 2021, the SESAR JU benefited from efficiency measures already implemented in previous years and implemented new measures to achieve further efficiency gains.

- **Collaboration with EUROCONTROL.** Considering that EUROCONTROL possesses an appropriate infrastructure and the necessary administrative, IT, communications and logistics support services, the SESAR 3 JU benefits from such infrastructure and services, implementing the SESAR JU–EUROCONTROL agreement.
- **Collaboration with the European Commission.** The SESAR JU benefits from synergies through the use of the European Commission's ICT systems and services (e.g. contracts with ICT service providers and suppliers). ICT systems supplied by the Commission are, in particular, related to:
    - financial management and accounting systems (ABAC);
    - HR management (SYSPER);
    - the management of Horizon Europe calls for proposals and grants;
    - procurement (e-procurement);
    - document management, namely the use of ARES (the European Commission's document management system).
- **Quality management.** The SESAR JU undertakes regular process improvement initiatives in the context of the SESAR JU QMS (see Section IV.11) supervised by the QICT Committee, in order to monitor the 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 SESAR JU's 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 continually improved since then. The SESAR JU has also prepared the implementation of modules in ARES to streamline communication with Commission services. While the preparation progressed well in 2021, the SESAR JU management decided to postpone the full deployment of the solution until the SESAR 3 JU was set up. Therefore, this project was still in progress at the end of 2021.
    - **Electronic workflows.** The managed configuration of electronic systems supporting quality and information processes and key workflows that can be operated either locally or remotely made it possible to implement teleworking measures with minimal impact on the SESAR JU's business continuity. The SESAR JU's ICT system, which includes collaboration platforms and electronic workflows, in combination with ABAC workflows, proved to be effective in supporting the most critical processes and those with strict deadlines.

- **Reduction in the number of staff missions.** In 2021, the number of missions undertaken by SESAR JU staff was reduced, with many activities, especially recurring monitoring activities (e.g. project reviews), replaced with videoconferences (see Section II.7.3). Most meetings with grant beneficiaries relating to ER, IR and VLD projects, other than critical meetings such as kick-off meetings and critical reviews, took place by videoconference, with significant benefits such as a reduced environmental footprint, increased efficiency and better work–life balance for participants. As a result of COVID-19 restrictions, the SESAR JU also regularly used online collaboration platforms for meetings, and increased staff familiarity with these systems is likely to mean that the number of staff missions continues to be lower than in the past, even after travel restrictions are removed.

4.14 Delegation and subdelegation

In 2021, pursuant to Article 40 of the SESAR JU's financial rules, the authorising officer of the SESAR JU delegated his power of budget implementation to the SESAR JU AOD, the Deputy Executive Director.

A first delegation was signed on 18 January 2021 and was valid from 31 December 2021. In view of the resignation of the authorising officer in July 2021, this delegation was replaced by a new delegation signed by the Executive Director *ad interim* and was valid from 5 July to 31 December 2021.

According to Article 40 of the SESAR JU's financial rules, the delegatee may subdelegate the powers received with the explicit agreement of the Executive Director. The AOD subdelegated his power of budget implementation to the AOSD, the Chief Administration Affairs. This delegation was signed on 18 January and was valid from 1 January to 31 December 2021.

The empowered staff members can act only within the limits of the powers expressly conferred upon them. The AOD can act only in the absence or unavailability of the authorising officer or on an ad hoc temporary basis formalised through the exchange of letters. The AOSD can act only in the absence of the AOD and can authorise transactions to a maximum amount of EUR 60 000.

In both cases, the delegatees are authorised to draw up individual budgetary commitments of appropriations, provisional budgetary commitments of appropriations, decisions on the award of financing agreements and public contracts, legal commitments, payment orders, and estimates of amounts receivable and recovery orders related to titles 1, 2 and 3 of the SESAR JU budget.

The power delegated to the AOD also covers transactions related to the H2020 guarantee fund.

The AOD and AOSD have signed a charter that identifies the tasks entrusted, their rights and duties, and the responsibilities they assume in their capacity as AOD and AOSD.

In connection with the powers delegated to them, the AOD and the AOSD assist the authorising officer in reporting on the performance of their duties in the form of a biannual activity report. This report contains financial and management information, including comments on the use made of these resources, information on the results of programmes operations or measures to achieve objectives set by the SESAR JU, information on the risks observed related to these programmes operations or measures, remarks on actions taken following observations of the discharge, ECA or internal auditors, and remarks on actions taken to remedy malfunctioning.

At the adoption of the single basic act on 19 November 2021, the delegation and subdelegation agreements stopped existing. In order to guarantee the business continuity, a transfer of the delegation of authority was adopted by the SESAR 3 JU Executive Director *ad interim* with limits of application compatible with the legal framework temporarily applicable during the absence of adopted

financial rules. The adoption of the new financial rules by the first Governing Board on 14 December 2021 permitted the delegation of the budget implementation authority.

Whereas the framework financial regulation applicable to the SESAR JU sets out that the delegatee may subdelegate the powers received with the explicit agreement of the director, the model financial regulation applicable to the SESAR 3 JU does not mention the possibility of subdelegation from the AOD to the AOSD. Therefore, two delegations from the authorising officer to the AOD were signed and were valid from 17 to 31 December 2022: one to the Deputy Executive Director and one to the Chief Administration Affairs.

According to Article 19 of the SESAR 3 JU's financial rules, the empowered staff members can act only within the limits of the powers expressly conferred upon them.

In both cases, the delegatees are authorised to draw up global budgetary commitments of appropriations; individual budgetary commitments of appropriations; provisional budgetary commitments of appropriations; decisions on the award of grants, prizes and contracts (including framework contracts); decisions on the award of financing agreements and public contracts; legal commitments; payment orders; estimates of amounts receivable and recovery orders; waives of the recovery of amounts receivable of less than EUR 5 000; the cancellation of amounts receivable of less than EUR 5 000; and the validation of transfers of appropriations related to titles 1, 2, 3 and 4 of the SESAR 3 JU budget.

The power delegated to the Deputy Executive Director also covers transactions related to title 5 of the SESAR 3 JU budget and to the guarantee fund.

In both cases, the delegatee can act only within the limits and during the specified period of application set for the power delegated to the Deputy Executive Director 'in the absence or unavailability of the authorising officer' and set for the power delegated to the Chief Administration Affairs 'in the absence of the Executive Director and the Deputy Executive Director' and for transactions of a maximum of EUR 60 000.

The AOD and AOSD have accepted the delegation and signed a charter that identifies the tasks entrusted, their rights and duties, and the responsibilities they assume in their capacity as AOD and AOSD.

In connection with the powers delegated to them, the AOD and AOSD assist the authorising officer in reporting on the performance of their duties in the form of a biannual activity report. This report contains financial and management information including comments on the use made of these resources, information on the results of programmes operations or measures to achieve objectives set by the SESAR JU, information on the risks observed related to these programmes operations or measures, remarks on actions taken following observations of the discharge, ECA or internal auditors, and remarks on actions taken to remedy malfunctioning.

The SESAR JU IAC performs twice a year an independent review of the transactions carried out by the AOD and AOSD and addresses a written report to the authorising officer with its conclusions.

4.15 Assessment by management

Based on the control procedures performed by staff of the SESAR 3 JU, a positive conclusion on the legality and regularity of transactions can be drawn.

This conclusion takes into consideration the need for the SESAR 3 JU to maintain a high level of efficiency of its internal control environment and to constantly assess and strengthen the existing

controls in order to implement the internal control framework and to ensure the achievement of the objectives in its annual work programme.

4.15.1 Overall budget implementation rate

As a result of budget monitoring throughout the year, the budget execution rate in 2021 was 298.32 % for revenue commitment appropriation execution and 90.37 % for expenditure commitment appropriation (see also Sections II.5.3.1 and II.5.3.2).

4.15.2 Legality and regularity

In order to ensure the sound financial management, legality and regularity of the underlying transactions, all transactions are submitted through the four-eyes principle in the preparation phase and in the payment phase. The *ex ante* control function is exercised at operational level – to verify the work performed during the initiation of the transaction to ensure that the required results are achieved – and at financial level, to verify the application of the rules.

The extensive *ex ante* controls helped prevent material errors and formal errors at all stages of the authorisation process (initiation, verification, authorisation and payment).

4.15.3 Procurement procedures

Owing to its focus on the transition process, the SESAR JU limited its maximum number of procurement procedures and dealt with 10 procurement procedures, including six very low-value procurements. In addition, the SESAR JU signed six interinstitutional framework service contracts, two direct service contracts and eight specific contracts implementing SESAR JU framework contracts / interinstitutional agreements. More details can be found in Section II.6.

4.15.4 Registration of exceptions report

As set out in Section III of the SPD for 2021–2023, the SESAR JU established an exceptions and non-compliance events management process. Initially authorised in 2018 ([73]), the SESAR JU internal process was updated in 2021 ([74]). This updated process takes into consideration Executive Director decision SJU/ED/761 dated 11 November 2021 for the adoption of an electronic workflow for the internal visas of the files (an electronic routing slip workflow) and internal control standard No 8 ([75]).

This process includes the maintenance of an ‘exceptions and non-compliance events register’ to manage and monitor possible deviations, which are not initially foreseen by the procedures submitted to the authorising officer with a justification for endorsement.

If such control overrides or deviations are approved before action is taken (*ex ante*), they are called ‘exceptions’. If they are detected after an action has been taken (*ex post*), they are known as ‘non-compliance events’. Non-compliance events can constitute a breach of existing regulatory and/or contractual provisions and can be the result of errors, flaws or even fraud. Non-compliance events

([73]) Executive Director decision No 647 of 23 March 2018.

([74]) Executive Director decision SJU/ED/762 of 15 November 2021, transferred to the SESAR 3 JU under Executive Director decision S3JU/ED/0001 dated 30 November 2021.

([75]) Internal control standard No 8 requires the SESAR JU to establish ‘a method … to ensure that all instances of overriding of controls or deviations from established processes and procedures are documented in exception reports, duly approved before action is taken and logged centrally’.

reflect a deficiency in existing controls. They cannot be authorised (as in *ex ante* cases), but should be reported by the appropriate management level.

In accordance with the abovementioned policy and process, in 2021, the SESAR JU recorded:

- one non-compliance event resulting from the non-activation of the H2020 guarantee fund and/or the issuing a recovery order due to the bankruptcy of a beneficiary (H2020 project 763702 (PercEvite));
- one exception linked to the extension of the duration of the contract governing the monitoring and maintenance of the SESAR JU premises' alarm system (CTR SJU/LC/327-CTR).

The exceptions and non-compliance events register is available on request and is consulted by the ECA during audits.

4.15.5 Audit results and recommendations

In 2021, no critical recommendations were issued or closed and, on 31 December 2021, no critical recommendations were open.

Actions in relation to recommendations issued by the IAS in 2021 (see Section IV.5) are in progress. Moreover, all previous audit recommendations stemming from the IAS, the ECA and the European Commission either have been formally closed or have been submitted for closure (see Section IV.7 for further detail).

4.15.6 Business continuity

Despite the COVID-19 crisis, the SESAR JU was able to ensure continuity of its operations and achieved all of its objectives with no major disruption to service, as described throughout this CAAR.

4.16 Statement of the manager in charge of risk management and internal control

I, the undersigned,

Manager in charge of risk management and internal control within the SESAR 3 Joint Undertaking,

In my capacity as manager in charge of risk management and internal control, declare that in accordance with the SESAR Joint Undertaking's internal control framework, I have reported my advice and recommendations on the overall state of internal control in the Joint Undertaking to the Executive Director.

I hereby certify that the information provided in the present consolidated annual activity report and in its annexes is, to the best of my knowledge, accurate, reliable and complete.

Brussels, 27 June, 2022

(Signed)

Peter Hotham

Deputy Executive Director

Manager in charge of risk management and internal control

SESAR Joint Undertaking

5 Management assurance

5.1 Governing Board's analysis and assessment

The Governing Board has assessed the 2021 CAAR and, having reviewed the document, notes the following:

- The SESAR JU met all of its key policy and operational objectives in 2021 as outlined in the Single Programming Document for 2021 to 2023 (2021–2023 SPD);
- The SESAR JU's key achievements in 2021 were the following:
    - the completion of release 10 (by September 2021), in line with the release plan published in 2019; the initiation of release 11; and the start of the planning and preparation of release 12, to be conducted in 2022–2023;
    - the supervision of ongoing projects under the IR-VLD Wave 2, IR-VLD Wave 3, ER 4 and VLD calls for proposals;
    - the organisation of and/or participation in major European and global events related to air traffic management and aviation, including the SESAR Innovation Days and several International Civil Aviation Organization events;
    - the communication of programme results and the promotion of scientific excellence through the SESAR Digital Academy and the Young Scientist Award;
    - The preparation of the new ATM partnership by establishing its governance structure and establishing relevant rules for its existence;
    - Preparation of the work programmes of the SESAR 3 JU;
    - Ensuring efficiency full continuity of operations between the two legal entities of SESAR JU and SESAR 3 JU;
- With these achievements, the SESAR JU completed its work programme for 2021 fully; the performance indicators show that all targets were met;
- In the context of the COVID-19 crisis and its financial impact on the SESAR JU Members, the JU has put in place a series of budgetary measures following a discussion supported at the Administrative Board's meeting of 7 May 2020. These measures aim to provide the Members and the aviation sector with immediate cash-flow support through measures that in 2021, in continuation of the measures implemented in 2020, will take the form of:
    - an increase in pre-financing rates from 20 % to 40 % for projects under the VLD Open 2 call and from 60 % to 80 % for projects under the Wave 2 (pre-financing of second instalments) and Wave 3 calls;
    - a temporary reduction of 20 % in the cash contributions requested from the Members other than the EU and Eurocontrol for the SESAR JU's running costs. The overall due amount will be regularised later on, on the basis of the actual accepted in-kind contribution costs of each Member under the SESAR 2020 Programme.
- the required building blocks of assurance remained in place throughout 2021 and continued to work adequately: management assessment, registration of exceptions and non-compliance events, audits, internal control and management systems, etc.;
- the main risks to the delivery of the SESAR JU's key objectives were identified and the relevant mitigating measures were taken, keeping overall risks under control and at an acceptable level of criticality.

Consequently, the Governing Board concludes that the 2021 CAAR accurately and adequately describes the work performed by the SESAR JU in 2021.

5.2 Review of the elements supporting assurance

This section provides information on the set of 'building blocks' that enables the Executive Director to obtain a full picture of the state of play of the SESAR JU, underpinning the reasonable assurance given by the authorising officer in his declaration of assurance of the annual activity report and allowing him to give adequate assurance to the Management Board.

5.2.1 Building block 1: Assessment of internal control systems

This assessment can be found in Section 4.11.3.

5.2.2 Building block 2: Register of exceptions

This assessment can be found in Section 4.15.

5.2.3 Building block 3: Audit results during the reporting period

Audit results and recommendations are presented in Sections 4.7 and 4.8.

Section IV.3 presents the results of H2020 *ex post* (project) audits. While the audit process for FP7 projects was carried out under the responsibility of the SESAR JU, the audit of H2020 cost claims is fully centralised in the CAS of the Common Implementation Centre ([76]).

5.2.4 Building block 4: Internal control systems

The assessment of the SESAR JU's internal control systems can be found in Section 4.11.2.

5.3 Reservations

The Executive Director *ad interim*, in his capacity as authorising officer, has signed the declaration of assurance, albeit qualified by the following reservation.

- A reservation for the U-space assigned revenue concerning six projects. The necessary corrective and preventive actions have been described in Section 4.3 of this report.

Following EC instructions, the JU has analysed the situation and provided the four steps analysis that is necessary in order to reach a sound conclusion allowing the Authorising Officer to qualify the declaration with a reservation and to estimate its impact in monetary terms:

Step 1 - calculating the detected error rate in the sample of transactions:

The audit findings indicate a 34% detected error rate, which is not considered as representative for the expenditure made under U-Space because the sampling was value-targeted and the detected error rate reflects only a conservative approach.

([76]) This is the CAS for the H2020 framework programme for R&I expenditure at the European Commission hosted by the Directorate-General for Research and Innovation.

Due to this fact, no residual error rate could be calculated in the remaining population.

Step 2 - estimating the financial exposure as 'amount at risk':

The amount at risk is calculated at EUR 611 000, which corresponds to the amount that needs to be recovered.

Step 3 - materiality:

The error rate in the 2020 expenditure is calculated at 8% which requires a reservation in the declaration of assurance and it is calculated as the amount at risk / entire expenditure for U-space in 2020 (i.e. EUR 611 000 / EUR 7 400 000).

Step 4 - impact on the Authorising Officer by Delegation's overall assurance and Declaration:

The overall impact for the SESAR 3 JU as a whole is not considered to be significant as the scope of the underlying issue concerns an activity (U-space) which represents a relatively small part of its overall budget.

Additionally, in terms of recovery, the SESAR 3 JU expects that the entire amount will be fully recovered.

5.4 Overall conclusions

On the basis of the above elements, the management provides reasonable assurance that all necessary control procedures are in place to guarantee the legality and regularity of the SESAR JU's activities, in line with the principles of economy, efficiency and effectiveness.

In conclusion, the management provides reasonable assurance that, overall, suitable controls are in place and are working as intended, risks are being appropriately monitored and mitigated, and necessary improvements and reinforcements are being implemented. Therefore, the Executive Director *ad interim*, in his capacity as authorising officer, has signed the declaration of assurance presented in Chapter VI.

6 Declaration of assurance

I, the undersigned, Executive Director *ad interim* of the SESAR Joint Undertaking,

In my capacity as authorising officer,

Declare that the information contained in this report gives a true and fair view.

State that I have reasonable assurance that the resources assigned to the activities described in this report have been used for their intended purpose and in accordance with the principles of sound financial management, and that the control procedures put in place give the necessary guarantees concerning the legality and regularity of the underlying transactions.

This reasonable assurance is based on my own judgement and on the information at my disposal, such as the results of the self-assessment, *ex post* controls, the work of the Internal Audit Service, the work of the Internal Audit Capability and the lessons learnt from the reports of the Court of Auditors for years prior to the year of this declaration.

Confirm that I am not aware of anything not reported here that could harm the interests of the agency.

However, the reservation on the U-space expenditure should be noted.

Brussels, 27 June 2022

(Signed)

Richard Frizon

Executive Director *ad interim*

SESAR Joint Undertaking

Annexes

Annex I. SESAR JU Organisation chart

Figure 18 shows the organisation chart of the SESAR JU applicable until 29 November 2021 as adopted by the SESAR JU Administrative Board with ADB(D)04-2021 signed on 12 February 2021.

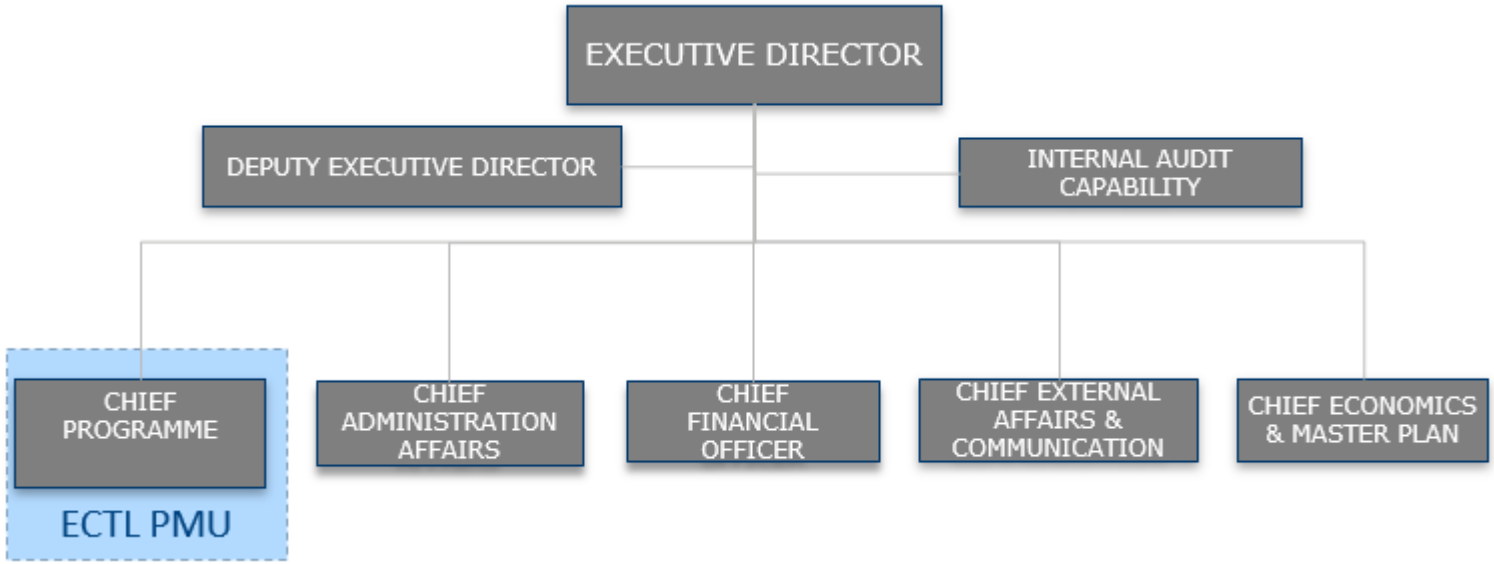


Figure 18: SESAR JU Organisation chart as at 29 November 2021

Annex II. Establishment plan and additional information on human resources management

Table 28: Staff policy plan for 2021

Function group and grade (AD, administrato; AST, assistant; CA, contract agent)	2020				2021			
	Authorised budget		Actually filled as of 31 December 2020		Authorised budget		Actually filled as of 31 December 2021	
	Permanent posts	Temporary posts	Permanent posts	Temporary posts	Permanent posts	Temporary posts	Permanent posts	Temporary posts
AD16								
AD15		1		1		1		
AD14								
AD13						1		
AD12		5		3		4		4
AD11		3		2		3		1
AD10		2		3		2		2
AD9		5		4		6		6
AD8		7		6		7		6
AD7		6		6		4		6
AD6		4		5		3		3
AD5								
Total AD		33		30		31		28
AST11								
AST10								
AST9		1		1		1		1
AST8								
AST7		1				1		
AST6								
AST5		1				2		1
AST4		2		2		1		2
AST3		1		1		1		1
AST2								1
AST1								
Total AST		6		4		6		6
AST/SC6								
AST/SC5								
AST/SC4								
AST/SC3								
AST/SC2								
AST/SC1								
Total AST/SC		0		0		0		0
Grand total TA		**39**		**34**		**37**		**34**
CA FG IV	n/a	0	n/a	1	n/a	1	n/a	1
CA FG III	n/a		n/a		n/a		n/a	
CA FG II	n/a		n/a		n/a		n/a	
CA FG I	n/a		n/a		n/a		n/a	
Total CA	n/a	0	n/a	1	n/a	1	n/a	1
SNE	n/a	3	n/a	3	n/a	2	n/a	
Total SNE	n/a	3	n/a	3	n/a	2	n/a	2

Table 29: Establishment plan

Key function	Function group, grade of recruitment	Indication whether the function is dedicated to administrative support or operations
Executive Director	AD14 – external	Operations
IAC	AD5 – external	50 % administrative support / 50 % operations
Assistant to the Executive Director	AST1 – external	Administrative support
Deputy Executive Director Corporate Affairs	AD12 – external	50 % administrative support / 50 % operations
Principal Research Scientist	AD10 – external	Operations
Head of Corporate Quality, Planning and Reporting	AD8 – external	50 % administrative support / 50 % operations
Head of Release Management and Validation	AD7 – external	Operations
Call coordinator	AD9 – external	Operations
Grant manager	AD6 – external	Operations
Grant manager	AD6 – external	Operations
Grant manager	AD6 – external	Operations
Grant manager	AD6 – external	Operations
ATM expert – Architecture and systems engineering	AD8 – external	Operations
Programme officer	AD7 – external	Operations
ATM expert – TMA, en route and network operations	AD6 – external	Operations
Chief External Affairs and Communications	AD10 – external	Operations
Senior external affairs officer	AD10 – external	Operations
Senior communications and media relations officer	AD5 – external	Operations
Communications and events officer	AD5 – external	Operations
Chief Economist and Master Planning	AD10 – external	Operations
Digital transformation and innovation	AD8 – external	Operations

Chief Finance Officer	AD12 – external	Administrative support
Head of Finance and Budget	AD8 – external	Administrative support
Financial monitoring and control	AD7 – external	Administrative support
Financial officer	AD6 – external	Administrative support
Financial officer	AD5 – external	Administrative support
Programming and planning officer	AST4 – external	Administrative support
Financial assistant	AST3 – external	Administrative support
Chief Administration Affairs	AD12 – external	Administrative
Project auditor	AD5 – external	Administrative
Head of Legal and Procurement	AD8 – external	Administrative support
Legal and procurement officer, data protection officer	AD5 – external	Administrative support
Legal and procurement officer	AD5 – external	Administrative support
Legal and procurement officer	AD5 – external	Administrative support
HR legal officer	AD7 – external	Administrative support
HR officer	AST7 – external	Administrative support
Administrative assistant	AST3 – external	Administrative support
Administrative assistant	AST2 – external	Administrative support

Annex III. Core business statistics

Annex III.1. Horizon 2020 scoreboards

Tables 30 and 31 follow the instructions on annual activity reports for joint undertakings operating under H2020.

Table 30: Scoreboard of H2020 common KPIs

Reference	Name of H2020 KPI	Definition	Data provided by SESAR 3 JU? ([77])	Value in 2020 ([78])	Value in 2021 ([79])
1	SME – proportion of participating SMEs introducing innovations new to the company or the market (covering the period of the project end date within reporting year + 3 years) (number of SMEs that have introduced innovations)	Number and percentage of participating SMEs that have introduced innovations to the company or to the market	No	54 (24 %) ([80])	31 (25 %) ([81])
2	SME – growth and job creation in participating SMEs (turnover of company, number of employees)	Turnover of company Number of employees	No	EUR 352 103 544.74 3 076 ([82])	EUR 326 069 344 2 964 ([83])

([77]) Data not provided by the SESAR JU are provided by beneficiaries through project reporting.
([78]) Data refer to the projects within SESAR 2020.
([79]) Data refer to the projects within SESAR 2020.
([80]) Data refer to projects with an end date between 2020 and 2023.
([81]) Data refer to projects with an end date between 2021 and 2023.
([82]) Value in 2020 re-run in 2021 for methodology adjustments. Data refer to projects with an end date between 2020 and 2023.
([83]) Data refer to projects with an end date between 2021 and 2023.

3	Number of publications in peer-reviewed, high-impact journals	Percentage of papers published in the top 10 % of journals, ranked by impact factor, by subject category	No	8 % ([84])	21 % ([85])
4	Patent applications and patents awarded in the area of the joint technology initiative (number of patents awarded)	Number of patent applications by theme Number of awarded patents by theme	No	Patent applications: 0 Awarded patents: 0 ([86])	Patent applications: 0 Awarded patents: 0 ([87])
5	Number of prototypes, testing activities and clinical trials	Number of prototypes, testing (feasibility/demonstration) activities and clinical trials	No	Prototypes: 292 Feasibility activities: 442 Clinical trials: not applicable ([88])	Prototypes: 368 Feasibility activities: 518 Clinical trials: 22 ([89])
6	Number of joint public–private publications in projects	Number of joint public–private publications and percentage of all relevant publications	No	66 (32 %) ([90])	79 (32 %) ([91])
7	New products, processes and methods launched into the market	Number of projects with new innovative products, processes and methods	No	Innovative products: 17 Innovative processes: 17 Innovative methods: 20 ([92])	Innovative products: 33 Innovative processes: 27 Innovative methods: 27 ([93])

([84]) Data refer to publication year 2020.
([85]) Data refer to publication year 2021.
([86]) Data refer to patent application year 2020.
([87]) Data refer to patent application year 2021.
([88]) Cumulative amounts referring to projects with a start date in 2016–2020.
([89]) Cumulative amounts referring to projects with a start date in 2016–2021.
([90]) Cumulative amounts referring to a publication date in 2016–2020.
([91]) Cumulative amounts referring to a publication date in 2016–2021.
([92]) Cumulative amounts referring to projects with a start date in 2016–2020.
([93]) Cumulative amounts referring to projects with a start date in 2016–2021.

8	Time to inform all applicants of outcome of evaluation	Number and percentage of information letters sent to applicants within target (153 days) Average time to inform (calendar days) Maximum time to inform (calendar days)	Yes	Information letters sent: 144 (100 %) Average time: 131 days Maximum time: 136 days ([94])	n/a ([95])
9	Redress after evaluation / evaluation review	Number of redress requests	Yes	0 %	0 %
10	Time to grant from call deadline to grant signature	Number and percentage of grants signed within target (8 months) Average time to grant (calendar days) Maximum time to grant (calendar days)	Yes	Grants signed: 43 (30 %) Average time: 219 Maximum time: 317 ([96])	Grants signed: 2 (100 %) Average time: 233 Maximum time: 244 ([97])
11	Time to sign from successful applicant letter	Number and percentage of grants signed within target (92 days) Average time to sign (calendar days) Maximum time to sign (calendar days)	Yes	Grants signed: 29 (55 %) Average time: 92 Maximum time: 181 ([98])	Grants signed: 2 (100 %) Average time: 74 Maximum time: 85 ([99])

([94]) Data referred to call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020.
([95]) Not applicable, as all information letters were sent in 2020.
([96]) Data refer to call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2.
([97]) Data refer to call H2020-SESAR-2020-1.
([98]) Data refer to call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2.
([99]) Data refer to call H2020-SESAR-2020-1.

12	Time to pay (percentage of payments that were on time) for pre-financing, interim payment and final payment	Average number of days for pre-financing (target: 30 days), interim payment (target: 90 days) and final payment (target: 90 days) Average number of days for administrative payments Number of experts appointed	Yes	100 % on time for pre-financing Average number of days for pre-financing: 15.5 Average number of days for interim payment: 64 Average number of days for final payment: 75 Average number of days for administrative payments: 16 Experts contracted: 66 ([100])	100 % on time for pre-financing Average number of days for pre-financing: 16 Average number of days for interim payment: 60 Average number of days for final payment: 78 Average number of days for administrative payments:18 Experts contracted: 24 ([101])
13	Vacancy rate (%)	Vacancy rate during the reporting period (%)	Yes	4.8 %	7.5 %
14	Budget implementation/execution: 1. % commitment to total budget 2. % of payments to total budget	Realistic yearly budget proposal and possibility to monitor and report on its execution, both in commitment and in payments, in line with the sound financial management principle	Yes	1. 94.63 % 2. 67.65 %	1. 69.47 % 2. 90.37 % ([102])
15	Administrative budget: number of late payments and percentage of total	Number and percentage of late payments	Yes	33 (6.75 %)	13 (4.53 %)

([100]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2.
([101]) Data refer to experts members of the Scientific Committee and monitors for projects of call H2020-SESAR-2019-1 and call H2020-SESAR-2020-2.
([102]) The percentages presented refer exclusively to titles 1, 2 and 3 (as explained in Section II.5.3 of the main text).

Table 31: Indicators for monitoring cross-cutting issues

Reference	Name of H2020 KPI	Definition	Data provided by SESAR JU? ([103])	Value in 2020 ([104])	Value in 2021 ([105])
16	Number of nationalities in H2020, applicants and beneficiaries	Number of nationalities of H2020 applicants and beneficiaries	No	32 ([106])	28 ([107])
17	Total amount of EU financial contributions, by Member State	Nationalities of H2020 beneficiaries and corresponding EU financial contribution	No	Austria: EUR 2 942 214 Belgium: EUR 2 149 282 Croatia: EUR 312 875 Cyprus: EUR 100 187 Czechia: EUR 955 054 Denmark: EUR 375 500 Estonia: EUR 0 Finland: EUR 430 500 France: EUR 11 752 103 Germany: EUR 11 170 822 Greece: EUR 602 500 Hungary: EUR 326 000 Ireland: EUR 350 991 Italy: EUR 879 856	Austria: EUR 2 983 952 Belgium: EUR 686 728 Croatia: EUR 87 500 Cyprus: EUR 0 Czechia: EUR 1 648 909 Denmark: EUR 1 003 931 Estonia: EUR 766 658 Finland: EUR 840 554 France: EUR 7 613 007 Germany: EUR 5 488 318 Greece: EUR 125 500 Hungary: EUR 176 250 Ireland: EUR 46 799 Italy: EUR 3 957 926

([103]) Data not provided by the SESAR JU are provided by beneficiaries through project reporting.
([104]) Data refer to the projects within SESAR 2020.
([105]) Data refer to the projects within SESAR 2020.
([106]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to submission or projects with a start year of 2020.
([107]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to submission or projects with a start year of 2021.

				Lithuania: EUR 0 Luxembourg: EUR 0 Netherlands: EUR 4 400 926 Poland: EUR 537 616 Portugal: EUR 485 000 Slovenia: EUR 0 Spain: EUR 11 960 546 Sweden: EUR 2 953 642 United Kingdom: EUR 4 469 515 ([108])	Lithuania: EUR 101 938 Luxembourg: EUR 351 488 Netherlands: EUR 3 029 501 Poland: EUR 1 265 317 Portugal: EUR 0 Slovenia: EUR 127 995 Spain: EUR 12 280 846 Sweden: EUR 1 186 138 United Kingdom: EUR 5 448 339 ([109])
18	Number of nationalities in H2020, applicants and beneficiaries (associated countries)	Number of nationalities of H2020 applicants and beneficiaries (associated countries)	No	5 (Iceland, Norway, Serbia, Switzerland, Turkey) ([110])	3 (Norway, Switzerland, Turkey) ([111])
19	Total amount of EU financial contributions, by associated country	Nationalities of H2020 beneficiaries and corresponding EU financial contribution	No	Iceland: EUR 336 250 Norway: EUR 800 000 Serbia: EUR 627 127 Switzerland: EUR 3 383 125 Turkey: EUR 1 154 250 ([112])	Norway: EUR 1 080 309 Switzerland: EUR 956 350 Turkey: EUR 76 250 ([113])
20	Proportion of EU financial contribution going to SMEs	Number of H2020 beneficiaries flagged as SMEs	No	52 SMEs 15.8 % ([114])	39 SMEs

([108]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([109]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.
([110]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to submission year of 2020.
([111]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to submission year of 2021.
([112]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([113]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.
([114]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.

		Percentage of EU contribution going to beneficiaries flagged as SMEs			14.2 % ([115])
21	Percentage of women in H2020 projects	Percentage of female participants in H2020 projects	No	30 % ([116])	29 % ([117])
22	Percentage of women project coordinators in H2020	Percentage of female MSc fellows, European Research Council principal investigators and scientific coordinators in other H2020 activities	No	24 % ([118])	24 % ([119])
23	Percentage of women in European Commission advisory groups, expert groups, evaluation panels, individual experts, etc.	Percentage of female members in advisory groups, panels, etc.	Yes	Administrative Board: 2 out of 28 (7 %) Evaluation panel: 4 out of 9 (44 %) Scientific Committee: 3 out of 10 (30 %) External observers: 1 out of 3 (33 %)	Administrative Board: 1 out 28 (3.6 %) Evaluation panel: n/a ([120]) Scientific Committee: 3 out of 10 (30 %) External observers: 1 out of 3 (33 %)
24	Proportion of non-EU country participants in H2020	Nationality of H2020 beneficiaries	No	TP: 22 (9 %) 9 nationalities ([121])	TP: 32 (23 %) 15 nationalities ([122])
25	Percentage of EU financial contribution attributed to non-EU country participants	Percentage of non-EU H2020 beneficiaries with EU financial contribution	No	0 ([123])	0 ([124])

([115]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.
([116]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([117]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.
([118]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([119]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.
([120]) No call evaluation took place in 2021.
([121]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([122]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.
([123]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([124]) Data refer to call H2020-SESAR-2019-1, call H2020-SESAR-2019-2, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.

26	Proportion of projects and EU financial contribution allocated to IAs	Number of IA proposals and projects properly flagged in the WP; follow-up at grant level	Yes	Number of IA projects: 5 ([125]) Percentage of IA projects out of all projects: 12 % IAs out of overall EU contribution: 31 %	Number of IA projects: 7 ([126]) Percentage of IA projects out of all projects: 50 % IAs out of overall EU contribution: 53 %
27	Within the IAs, proportion of EU financial contribution focused on demonstration and first-of-a-kind activities	Topics properly flagged in the WP; follow-up at grant level	Yes	100 % (all IA projects are VLD activities) ([127])	100 % (all IA projects are VLD activities) ([128])
28	Scale of impact of projects (high TRL)	Number of projects between TRL4 and TRL6 and between TRL5 and TRL7	Yes	Projects up to TRL2 or equivalent operational concept maturity level (ER): 42 Projects at TRL2 to TRL6 or equivalent operational concept maturity level: 9 Projects at TRL6 or TRL7 or equivalent operational concept maturity level: 19 Projects that address transversal activities (i.e. non-directly TRL or operational concept-related activities): 3	Projects up to TRL2 or equivalent operational concept maturity level (ER): 41 Projects at TRL2 to TRL6 or equivalent operational concept maturity level: 13 Projects at TRL6 or TRL7 or equivalent operational concept maturity level: 14 Projects address transversal activities (i.e. non-directly TRL or operational concept-related activities): 3
29	Percentage of H2020 beneficiaries from the private for-profit sector	Number and percentage of total H2020 beneficiaries classified by type of activity and legal status	Yes	177 out of 348 (50.9 %) for PRC ([129]) IR: 30 out of 38 (79 %) VLD: 52 out of 66 (79 %)	167 out of 242 (69 %) for PRC ([130]) IR: 81 out of 107 (76 %) VLD: 77 out of 113 (68 %)

([125]) Amounts refer to call H2020-SESAR-2019-1, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([126]) Amounts refer to call H2020-SESAR-2019-1, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.
([127]) Amounts refer to call H2020-SESAR-2019-1, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([128]) Amounts refer to call H2020-SESAR-2019-1, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.
([129]) Amounts refer to call H2020-SESAR-2019-1, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([130]) Amounts refer to call H2020-SESAR-2019-1, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.

30	Proportion of EU financial contribution going to private for-profit entities (enabling and industrial technology and Part III of H2020)	H2020 beneficiaries classified by type of activity and corresponding EU contribution	Yes	EUR 35 210 989 for PCR out of EUR 71 374 590 (49 %) ([131])	EUR 32 661 167 for PCR out of EUR 51 330 501 (64 %) ([132])
31	EU financial contribution for public–private partnerships (Article 187)	EU contribution to public–private partnerships (Article 187)	Yes	EUR 496 953 067 ([133])	EUR 549 209 833 ([134])
32	Public–private partnerships leverage: total amount of funds leveraged through Article 187 initiatives, including additional activities, divided by the EU contribution	Total funding made by private actors involved in public–private partnerships • in-kind contributions already committed by private members to projects selected for funding • additional activities (i.e. research expenditures / investment of industry in the sector, compared with previous year)	Yes	See indicator 40 (Table 32)	See indicator 40 (Table 32)
33	Dissemination and outreach activities other than publications in peer-reviewed journals	Type of dissemination activity can be chosen from a drop-down list. Number of events, funding amount and number of	No	Not reported	Events: 543 Meetings: 207 Open days: 149 Other media: 176

([131]) Amounts refer to call H2020-SESAR-2019-1, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([132]) Amounts refer to call H2020-SESAR-2019-1, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.
([133]) Cumulative amounts referring to projects with a start date in 2016–2020.
([134]) Cumulative amounts referring to projects with a start date in 2016–2021.

		people reached thanks to the dissemination activities			Publications: 232 Social media: 133
34	Proposal evaluators by country	Nationality of proposal evaluators	Yes	Austria: 2 Belgium: 1 Cyprus: 1 Finland: 2 France: 5 Germany: 6 Greece: 4 Hungary: 1 Ireland: 1 Italy: 7 Netherlands: 3 Poland: 3 Portugal: 4 Romania: 5 Slovenia: 1 Spain: 6 Sweden: 3 Switzerland: 1 Turkey: 7 United Kingdom: 3	n/a ([135])
35	Proposal evaluators by organisation's type of activity	Type of activity of evaluators' organisations	Yes	Higher education: 9 Research organisation: 28 Public organisation: 10 Other: 19	n/a ([136])

([135]) Not applicable as no call evaluation.
([136]) Not applicable as no call evaluation.

36	Participation of research and technology organisations and universities in public–private partnerships	Number of participations of research and technology organisations in funded projects and percentage of the total Number of participations of universities in funded projects and percentage of the total Percentage of budget allocated to research and technology organisations and to universities		70 (REC) out of 348 (all entity types) (20 %) 77 (HES) out of 348 (all entity types) (22 %) Budget allocated to research and technology organisations and to universities: 30.3 % ([137])	41 (REC) out of 242 (all entity types) (17 %) 13 (HES) out of 242 (all entity types) (5 %) Budget allocated to research and technology organisations and to universities: 19.1 % ([138])
37	The objective is to ensure that research projects funded are compliant with provisions on ethics efficiency	Proposals not granted because of non-compliance with ethical rules as a percentage of proposals invited to grant (target: 0 %); time to ethics clearance (target: 45 days) ([139])	Yes	0 %	0 %
38	Error rate (for H2020 grants)	Representative error rate (%) Residual error rate (%)	Yes	Representative error rate: 3.46 % Residual error rate: 2.49 %	Representative error rate: 0.67 % Residual error rate: 0.57 %
39	Implementation of *ex post* audit results for H2020 projects	Percentage of cases implemented out of total cases (total EUR million)	Yes	33 % (EUR 314 407 / EUR 943 472) ([140])	59 % (EUR 1 011 199 / EUR 1 721 290)

([137]) Amounts refer to call H2020-SESAR-2019-1, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2020.
([138]) Amounts refer to call H2020-SESAR-2019-1, call H2020-SESAR-2020-1 and call H2020-SESAR-2020-2 referring to projects with a start year of 2021.
([139]) The SESAR 3 JU provides ethics clearance together with the rest of the grant agreement preparation feedback, meaning within at least 90 days.
([140]) Cumulative amounts refer to 2017, 2018, 2019 and 2020.

Annex III.2. Scoreboard of key performance indicators specific to the SESAR 3 Joint Undertaking

Table 32 provides an overview of KPIs specific to the SESAR 3 JU.

Table 32: KPIs specific to the SESAR 3 JU – 2020 and 2021

Reference	Name of H2020 KPI	Definition	Value in 2020	Value in 2021	Target by 2024
40	Public–private partnerships leverage: in-kind contributions committed by private members to SESAR 2020 projects selected for funding	Ratio of private to public funding in all project types (see Section I.8 for explanation)	**Programme targets** Method 1 (interim evaluation): 0.75 Method 2 (EU body leverage): 0.78 Method 3 (H2020): 1.78 **Partnership leverage: 1.66**	**Programme targets (estimates)** Method 1 (interim evaluation): 0.95 Method 2 (EU body leverage): 1.0 Method 3 (H2020): 2.00 **Partnership leverage (estimate): 1.64** ([141])	**Programme targets** Method 1 (interim evaluation): 1.40 Method 2 (EU body leverage): 1.44 Method 3 (H2020): 2.44 **Partnership leverage: 1.95**
41	Completion of SESAR 2020 programme	Actual versus planned percentage of each project that had been completed as of the end of the reporting period	10 calls for proposals completed of the 10 planned at the end of 2020 85 grants completed + 2 terminated 67 grants in execution 2 grants in preparation	10 calls for proposals completed of the 10 planned at the end of 2021 84 grants completed + 2 terminated 70 grants in execution	100 %

([141]) 2021 estimate is subject to receipt of validated financial figures from the Members in line with the reporting cycle.

Reference	Name of H2020 KPI	Definition	Value in 2020	Value in 2021	Target by 2024
42	Delivery of SESAR 2020 solutions	Percentage of solutions ready for pre-industrialisation (V3/TRL6) ([142]) compared with plan ([143])		67 %	100 %

In addition, the European ATM Master Plan sets out performance ambitions (PAs) that the SES initiative should achieve by 2035, provided SESAR solutions can be deployed in an optimal and timely manner. Table 33 provides an overview of the SES performance scheme, showing KPAs and the related KPIs and PAs.

Table 33: SES performance scheme set out in the European ATM master plan

Reference	ATM Master Plan SES PA/KPA	KPI	ATM Master Plan overall SESAR 2020 PA (versus baseline of 2012)
43	Cost-efficiency	PA1	30–40 % reduction in air navigation service costs per flight
44	Operational efficiency	PA2	3–6 % reduction in flight times
		PA3	5–10 % reduction in fuel burn
		PA4	Arrival predictability: 70 % of flights arriving at gate within a 2-minute predicted time window
45	Capacity	PA5	10–30 % reduction in departure delays
		PA6	5–10 % additional flights at congested airports
		PA7	System able to handle 80–100 % more traffic
46	Environment	PA8	5–10 % reduction in CO_2 emissions
47	Safety	PA9	Safety improved by a factor of 3–4
48	Security	PA10	No increase in ATM-related security incidents resulting in traffic disruption

([142]) As per the release 7 close-out report, release 8 close-out report, release 9 close-out report, release 10 close-out report, release 11 close-out report and release 12 close-out report.
([143]) Release 7 plan, release 8 plan, release 9 plan, release 10 plan, release 11 plan and release 12 plan.

The SESAR programme is expected to contribute significantly to the SES performance scheme. That contribution is defined in the SESAR performance framework, which is composed of KPAs (SESAR KPAs and KPIs, linked to SES KPAs and KPIs) and the overall SESAR 2020 ambition; it was updated in 2017 to recognise the achievements of the SESAR 1 programme and to set the objectives for the SESAR 2020 programme.

In 2019, in continuation of the activities conducted in previous years, in collaboration with its members and with the support of project PJ19, the SESAR JU assessed the performance benefits in each KPA expected to result from the candidate solutions. A consolidation exercise conducted in 2019 gave the results set out in Table 34 (the achievements in Table 34 are based on only those solutions that have reached the V3/TRL6 maturity level, and exclude the results of candidate solutions that have not yet reached that maturity level).

Table 34: Performance ambitions, validation target starting point and SESAR 2020 initial performance assessment results (expectations)

KPA	Overall SESAR 2020 ambition	Units	Cumulative SESAR 1 + SESAR 2020 V3 achievement
Safety	–51 %	Reduction in accidents	–36.5 %
Airport capacity (CAP3)	10 %	Increase in peak hourly throughput	21.4 %
TMA capacity (CAP1)	47 %	Increase in peak hourly throughput	27.7 %
En route capacity (CAP2)	49 %	Increase in peak hourly throughput	48.8 %
Punctuality (PUN1)	7 %	Increase in proportion of flights departing within 3 minutes (either way) of scheduled off-block time	4.3 %
Predictability (PRD1)	96 %	Reduction in variance of block-to-block flight time	45.3 %
Environment / fuel efficiency (FEFF1)	500	Fuel saving (kg per flight)	147.4
ATCO productivity (CEF2)	97.7 %	Increase in ATCO productivity	74.8 %
Technology cost (CEF3)	43.4 %	Reduction in technology cost per flight	30.8 %

Annex IV. Assessment of the internal control system

Table 35: Indicators for the assessment of the internal control system implementing the SESAR 3 JU's internal control strategy

ID	Control Description	Type	Target ([144])	Measured value	Measurement frequency	Latest measurement (date of measurement)
CONTROL ENVIRONMENT						
1. The SESAR JU demonstrates a commitment to integrity and ethical values						
C1P01-01	% of managers/staff that participated in the SESAR JU corporate training on ethics	Minimum %	3	94 %	Yearly	31 December 2021
C1P01-02	An annual reminder about declarations of conflict of interest was sent to all managers and staff	Score 0–3	3	3	Yearly	31 December 2021
C1P01-03	A code of conduct / ethical guidance exists and all staff members have access to it in the IDMS	Score 0–3	3	3	Yearly	31 December 2021
2. The Board demonstrates independence from management, and exercises oversight of the development and performance of internal control						
C1P02-01	The SESAR JU provides information for and participates in regular coordination mechanisms so that the Commission, and in particular the Directorate-General for Mobility and Transport, exercises effective oversight of the SESAR JU activities	Score 0–3	3	3	Quarterly	31 December 2021
C1P02-02	Administrative Board meetings regularly deal with the topics of risk management, risk allocation and internal control	Score 0–3	3	3	Yearly	31 December 2021
C1P02-03	Management has a clear view on the specific activities they are responsible for, in compliance with their job description, and keeps track of the main issues identified	Score 0–3	3	3	Weekly	7 March 2022

([144]) 0, not implemented; 1, limited implementation; 2, implementation in progress; 3, fully implemented.

C1P02-04	The director in charge of risk management and internal control signs Appendix 3 of the internal control framework, 'Statement of the director in charge of risk management and internal control' A declaration of assurance (Appendix 2 of the internal control framework) is signed annually by the authorising officer	Score 0–3	3	3	Yearly	31 December 2021
3. Management establishes (with political oversight) structures, reporting lines, and appropriate authorities and responsibilities in the pursuit of objectives						
C1P03-01	Clear management structures are established and implemented on every level of the organisation; notably roles and tasks are clearly defined in the financial circuits The supervisory activities focus particularly on high-risk areas	Score 0–3	3	3	Quarterly	31 December 2021
C1P03-02	Each job in the SESAR JU is linked with SESAR JU's objectives and priorities	Score 0–3	3	3	Yearly	31 December 2021
C1P03-03	Managers have a clear view on the activities within their teams and keep track of the main issues identified through regular team meetings	Score 0–3	3	3	Half-yearly	31 December 2021
4. The SESAR JU demonstrates a commitment to attract, develop and retain competent individuals in line with objectives						
C1P04-02	The catalogue of training course sessions takes into account the skills needed at SESAR JU level in accordance with the learning and development policy	Score 0–3	3	3	Yearly	31 December 2021
C1P04-03	The SESAR JU complies with the rules of promotion within the organisation, and vacancies are open to internal candidates	Score 0–3	3	3	Yearly	31 December 2021
5. The SESAR JU holds individuals accountable for their internal control responsibilities in the pursuit of objectives						
C1P05-01	The SESAR JU implements a career development review for SESAR JU staff in which: • mutual expectations are set and responsibilities are clearly allocated; • performance is reviewed and assessed on a yearly basis; • reclassification is decided	Score 0–3	3	3	Yearly	31 December 2021
RISK ASSESSMENT						
6. The SESAR JU specifies objectives with sufficient clarity to enable the identification and assessment of risks relating to objectives						
C2P06-01	Number of critical and very important recommendations from internal auditors	Maximum number	1	0	Yearly	31 December 2021
C2P06-02	Number of financial / non-financial exceptions and non-compliance events	Maximum number	4	2	Yearly	31 December 2021

C2P06-03	The SESAR JU has a mission statement, clearly stated in a formalised document and easily accessible to all	Score 0–3	3	3	Yearly	31 December 2021
C2P06-04	The SPD clearly states the order of priorities among the main tasks in case of significant changes	Score 0–3	3	3	Yearly	31 December 2021
C2P06-05	The SESAR JU monitors the achievement of objectives through the indicators. Management ensures that all abnormalities in the progress of the objectives' achievement are reported when appropriate	Score 0–3	3	2	Quarterly	31 December 2021
7. The SESAR JU identifies risks to the achievement of its objectives across the organisation and analyses risks as a basis for determining how the risks should be managed						
C2P07-01	Management regularly reviews progress towards the specific objectives, and strategic and operational risks in the SESAR JU have been identified/assessed at appropriate level	Score 0–3	3	3	Half-yearly	31 December 2021
C2P07-02	Management puts mitigation plans in place for the risks identified in the risk register and regularly monitors their implementation	Score 0–3	3	3	Half-yearly	31 December 2021
8. The SESAR JU considers the potential for fraud in assessing risks to the achievement of objectives						
C2P08-01	The SESAR JU has an up-to-date anti-fraud strategy (not older than 3 years), which based on a stand-alone risk assessment	Score 0–3	3	3	Yearly	31 December 2021
C2P08-02	Number of opened and ongoing OLAF cases during the reporting year	Maximum number			Yearly	31 December 2021
C2P08-03	The SESAR JU informs its staff about the rules relating to conflicts of interest, fraud prevention and reporting of irregularities	Score 0–3	3	3	Yearly	31 December 2021
9. The SESAR JU identifies and assesses changes that could significantly affect the internal control system						
C2P09-01	A procedure exists for updating the objectives to take into account significant changes in activities and priorities	Score 0–3	3	3	Quarterly	31 December 2021
CONTROL ACTIVITIES						
10. The SESAR JU selects and develops control activities that contribute to the mitigation (to acceptable levels) of risks to the achievement of objectives						
C3P10-01	A control strategy exists and has been reviewed/updated and staff have been made aware of it	Score 0–3	3	3	Yearly	31 December 2021
C3P10-02	Number of business continuity exercises performed during the year for which lessons learnt are documented and implemented	Minimum number	0	0	Yearly	31 December 2021
C3P10-03	Number of security exercises performed during the year for which lessons learnt are documented and implemented	Minimum number	1	0	Yearly	31 December 2021

C3P10-04	ABAC access rights are reviewed once a year	Score 0–3	3	3	Yearly	25 May 2021
C3P10-05	A list of critical functions exists	Score 0–3	3	3	Yearly	31 December 2021
C3P10-06	The SESAR JU has a business continuity plan	Score 0–3	3	3	Yearly	31 December 2021
11. The SESAR JU selects and develops general control activities over technology to support the achievement of objectives						
C3P11-01	Number of IT security incidents with an impact on the confidentiality, integrity or availability of information systems, reported during the year	Maximum number	0	0	Monthly	16 February 2022
C3P11-02	Statistics on system downtime, server capacity and other performance indicators are regularly analysed System performance issues are reported to the appropriate management level	Score 0–3	3	3	Monthly	16 February 2022
C3P11-03	Feedback from IT users regarding system performance is collected and analysed	Score 0–3	3	3	Yearly	31 December 2021
C3P11-04	The SESAR JU has defined the appropriate organisation for the management of the information systems it uses (generally in the form of an IT Steering Committee) Each information system owned by the SESAR JU possesses a clearly identified business owner (and is overseen by a steering committee) The IT Steering Committee takes appropriate action if necessary	Score 0–3	3	3	Quarterly	31 December 2021
12. The SESAR JU deploys control activities through corporate policies that establish what is expected and through procedures that put policies into action						
C3P12-01	Exceptions and non-compliance events are systematically reported in the exception register according to defined and documented procedures	Score 0–3	3	3	Yearly	31 December 2021
C3P12-02	A policy and processes and procedures for information security exist, and staff have been made aware of them	Score 0–3	3	2	Yearly	31 December 2022
C3P12-03	A policy and processes and procedures for document management exist, and staff have been made aware of them	Score 0–3	3	3	Yearly	31 December 2022
C3P12-04	A policy and processes and procedures for data protection exist, and staff have been made aware of them	Score 0–3	3	3	Yearly	31 December 2021
C3P12-05	A policy and processes and procedures for public access to documents exist, and staff have been made aware of them	Score 0–3	3	3	Yearly	31 December 2021
C3P12-06	Appropriate control procedures are in place for the SESAR JU's main operational and financial processes and for the main ICT systems and services	Score 0–3	3	3	Yearly	31 December 2022
C3P12-07	The main SESAR JU processes are defined and described/documented and are applied in practice	Score 0–3	3	3	Half-yearly	31 December 2022

INFORMATION AND COMMUNICATION						
13. The SESAR JU obtains or generates and uses relevant quality information to support the functioning of internal control						
C4P13-01	The SESAR JU implements a quality policy and a quality manual that includes reference to internal control and its monitoring	Score 0–3	3	3	Yearly	31 December 2022
14. The SESAR JU internally communicates information, including objectives and responsibilities for internal control, necessary to support the functioning of internal control						
C4P14-01	The SESAR JU has an internal communication strategy in place	Score 0–3	3	3	Yearly	31 October 2021
C4P14-02	Regular team meetings and staff briefings take place to share information within the teams at various levels	Score 0–3	3	3	Quarterly	31 December 2021
C4P14-03	Arrangements are in place to ensure that management and staff are informed of other unit's, department's or the SESAR JU's decisions/projects/initiatives that may affect their responsibilities and tasks	Score 0–3	3	3	Half-yearly	31 December 2021
15. The SESAR JU communicates with external parties about matters affecting the functioning of internal control						
C4P15-01	Communication activities are aligned with the European Commission political priorities	Score 0–3	3	3	Half-yearly	31 December 2021
C4P15-02	The Chief Communication and External Affairs brings the communication planning to the Corporate Management Team for approval	Score 0–3	3	3	Yearly	31 January 2022
C4P15-03	An external communication strategy and an implementation plan exist	Score 0–3	3	3	Yearly	31 October 2021
MONITORING ACTIVITIES						
16. The SESAR JU selects, develops and performs ongoing and/or separate assessments to ascertain whether the components of internal control are present and functioning						
C5P16-01	Specific and continuous assessment exercises have been coordinated horizontally in the context of the internal control framework	Score 0–3	3	3	Yearly	28 February 2022
C5P16-02	The SESAR JU performs regular staff surveys (every 2–3 years) to monitor the commitment and satisfaction of staff	Score 0–3	3	3	Yearly	31 December 2021
17. The SESAR JU assesses and communicates internal control deficiencies in a timely manner to those parties responsible for taking corrective action, including senior management, as appropriate						
C5P17-01	The results of the continuous and specific assessment have been discussed with senior management and the Board	Score 0–3	3	3	Yearly	31 December 2021

C5P17-02	The results of the continuous and specific assessment have been properly disclosed in the CAAR	Score 0–3	3	3	Yearly	1 July 2021

Annex V. Provisional/final annual accounts

The provisional annual accounts for 2021 are provided in a separate document, which was officially handed over to the budgetary authorities, the ECA and the external auditors.

Annex VI. Materiality criteria

The assessment of the effectiveness of the SESAR 3 JU control system for H2020 grants is based mainly, but not exclusively, on *ex post* audits' results. The effectiveness is expressed in terms of detected and residual error rates, calculated on a representative sample on an annual and multiannual basis.

The starting point to determine the effectiveness of the controls in place is the cumulative level of error expressed as the percentage of errors in favour of the SESAR 3 JU, detected by *ex post* audits, measured with respect to the amounts accepted after *ex ante* controls.

However, to take into account the impact of the *ex post* controls, this error level is adjusted by subtracting:

- errors detected and corrected as a result of the implementation of audit conclusions;
- errors corrected as a result of the extension of audit results to non-audited contracts with the same beneficiary.

This results in a residual error rate, which is calculated as follows:

$$\mathrm{Re}\,sER\% = \frac{(\mathrm{Re}\,pER\% * (P - A)) - (\mathrm{Re}\,pERsys\% * E)}{P}$$

where:

- **Res*ER%*** represents the residual error rate, expressed as a percentage;
- **Rep*ER%*** represents the representative error rate, or error rate detected in the representative sample, in the form of a weighted average error rate, expressed as a percentage and calculated as described below;
- **Rep*ERsys%*** represents the portion of the RepER% representing negative systematic errors, expressed as a percentage;
- ***P*** represents the total requested SESAR contribution (EUR) in the auditable population (i.e. all paid financial statements);
- ***A*** represents the total requested SESAR contribution (EUR) as approved by financial officers of all audited financial statements (this will be collected from audit results);
- ***E*** represents the total non-audited requested SESAR contribution (EUR) of all audited beneficiaries.

The representative error rate will be established as a weighted average error rate identified for an audited representative sample.

The weighted average error rate will be calculated according to the following formula:

$$\mathrm{Re}pER\% = \frac{\Sigma(er)}{A}$$

where:

- **$\sum$ (*er*)** represents the sum of all individual errors of the sample – only the errors in favour of the JU will be taken into consideration;
- ***A*** represents the total amount (EUR) of the audited sample.

Annex VI.1. Multiannual approach

As a result of its multiannual nature, the effectiveness of the SESAR 3 JU's controls can be fully measured and assessed only at the final stages of the programme's lifetime, once the *ex post* audit strategy has been fully implemented and systematic errors have been detected and corrected.

The control objective is to ensure, for the SESAR H2020 programme, that the residual error rate, which represents the level of errors that remain undetected and uncorrected, does not exceed 2 % of the total expense recognised until the end of the programme.

In the case of the residual error rate being higher than 5 %, a reservation should be made and an additional action plan should be drawn up.

These thresholds are consistent with those established by the Commission and the ECA for their annual assessment of the effectiveness of the control systems operated by the Commission.

Notwithstanding the multiannual span of the control strategy, the Executive Director is required to sign a statement of assurance for each financial year. In order to determine whether to qualify this statement of assurance with a reservation, the effectiveness of the control systems in place needs to be assessed not only for the year of reference, but also from a multiannual perspective, to determine whether it is possible to reasonably conclude that the control objectives will be met in the future as foreseen.

In view of the crucial role of *ex post* audits, this assessment needs to check, in particular, whether the scope and results of the *ex post* audits carried out until the end of the reporting period are sufficient and adequate to meet the multiannual control strategy goals.

Annex VI.2. Adequacy of the scope

The quantity and adequacy of the (cumulative) audit effort carried out until the end of each year is to be measured by comparing the planned with the actual volume of audits completed.

The data are to be shown per year and cumulated, in line with the current annual activity report presentation of error rates.

The Executive Director should form a qualitative opinion to determine whether deviations from the plan are of such significance that they seriously endanger the achievement of the control objective for the programmes. If this were the case, he would be expected to qualify his annual statement of assurance with a reservation.

Annex VII. Composition of the Administrative Board as of 30 November 2021

Table 36: Composition of the Administrative Board as of 30 November 2021

SESAR JU founding members	Member	Alternate
EU	Mr Henrik Hololei (Chair), European Commission	Mr Filip Cornelis
EUROCONTROL	Mr Eamonn Brennan (Deputy Chair), EUROCONTROL	Mr Philippe Merlo
SESAR JU members	**Member**	**Alternate**
Airbus	Mr Bruno Darboux	Mr Hugues de Beco
AT-One consortium	Prof. Dr-Ing. Dirk Kügler	Dr Helmut Többen
B4-consortium	Ms Magdalena Kukuła	Mr Lubos Hlinovsky
COOPANS	Mr Robert Schneebauer	
Dassault Aviation	Mr Alain Boucher	Ms Catherine Champagne
DFS	Mr Dirk Mahns	Mr Gerard Tauss
DSNA		Mr Philippe Barnola
ENAIRE	Mr Angel Luis Arias	Ms Mariluz de Mateo
ENAV	Mr Alessandro Ghilari	Mr Cristiano Cantoni
Frequentis	Mr Hermann Mattanovich	Mr Michael Holzbauer
Honeywell	Mr George Papageorgiou	Mr Sander Roosendaal
Indra	Mr Rafael Gallego Carbonell	Mr Ramon Tarrech
Leonardo	Mr Luigi Iacometta	Mr Fabio Ruta
NATMIG	Mr Trond Runar Hagen	Mr Trond Bakken
NATS	Mr Dave Curtis	
SEAC	Mr Frank Pötsch	Mr Fredrik Nygaard
Skyguide	Mr Thomas Buchanan	Mr Pascal Latron
Thales LAS France SAS	Mr Luc Lallouette	Mr Todd Donovan
Thales AVS France SAS	Mr Olivier de la Burgade	Mr Pascal Combe
Stakeholder representatives	**Member**	**Alternate**
Military	MG (ret.) Eric Labourdette	Mr Per Coulet Mr Emilio Fajardo
Civil users of airspace	Mr Giancarlo Buono	Mr Robert Baltus
	Ms Sylviane Lust (permanent observer)	

ANSPs	Ms Tanja Grobotek	Mr Eduardo Garcia Gonzalez
Equipment manufacturers	Mr Vincent de Vroey	Mr Benjamyn Scott
Airports	Mr Olivier Jankovec	Mr Aidan Flanagan
Staff in the ATM sector	Mr Michele Altieri	Mr Theodore Kyritsis
Scientific community	Prof. Peter Hecker	Prof. Jacco Hoekstra
Permanent observers	**Member**	**Alternate**
European Commission Directorate-General for Research and Innovation	Mr Sebastiano Fumero	
Permanent representatives	**Member**	**Alternate**
SESAR JU Executive Director	Mr Florian Guillermet (until 4 July 2021)	
SESAR JU Executive Director *ad interim*	Mr Richard Frizon (as of 5 July 2021)	
SESAR JU Deputy Executive Director	Mr Peter Hotham	
SESAR JU Chief Administration Affairs	Mr José Calvo Fresno	
SESAR JU Internal Audit	Ms Véronique Haarsma	
Secretary of the Board	Ms Ilaria Vazzoler	

Annex VIII. Composition of the Governing Board as of 31 December 2021

Considering that on 31 December 2021, the composition of the Governing Board was in progress, and in several cases the appointment process of the alternate representatives was ongoing, only the name of the main representative is reported in Table 37.

Table 37: Composition of the Governing Board as of 31 December 2021

Founding Member name	Name of main representative
Aena	Amparo Brea Álvarez
Aeroport de Paris	M. Jean-Marc Flon
Aeroporti di Roma	Marco Pellegrino
Airbus SAS	Jean François Alonso
Air France	Alain Hervé Bernard
Air Navigation Services Czech Republic (ANS CR)	Jan Klas
Airtel ATN Lt	Giulio Di Tillio
Alliance for New Mobility Europe (AME)	Christoph Raab
Athens International Airport	George Tzavaras
Austro Control	Günter Tree
Boeing Aerospace Spain	Enrique Casado
Brussels Airport Company	Erik Watzeels
Bulatsa	Georgi Peev
CIRA	Marcello Kivel Mazuy
Collins Aerospace Ireland Limited	Ray Foley
Croatia Control	Dario Grgurić
Deutsche Lufthansa AG	Marcus Schnabel
DFS	Friedrich-Wilhelm Menge
DLR	Dirk Kügler
Drone Alliance Europe	Lucas van Oostrum
DSNA	Frederic Guignier
Easyjet Europe Airline Gmbh	Hugh McConnellogue
ENAC	Georges Mykoniatis
ENAIRE	Angel Luis Arias Serrano
ENAV	Alessandro Ghilari
EUROCONTROL	Eamonn Brenann

Flughafen München	Frank Poetsch
Frequentis	Michael Holzbauer
Honeywell	George Papageorgiou
Hungaro Control	Zoltan Vekey
Indra	Ramón Tarrech Masdeu
Irish Aviation Authority	Gerald Caffrey
Københavns Lufthavne (Copenhagen Airports A/S)	
Leonardo	Luisa Propato
LFV	Ulf Thibblin
LVNL	Maartje van der Helm
Naviair	Mikael Eriksson
NAV Portugal	Carlos Alves
NLR	P.L.J. Eijssen
ONERA	Sébastien Aubry
PANSA	Magdalena Kukuła
Pipistrel	Tine Tomažič
Prague Airport	Tomáš Vláčil
ROMATSA	Adrian Cojoc
Ryanair	Conor Gillardy
Saab	Mr Lars Jernbäcker
Safran	Olivier Ruas
Schiphol	Erik Derogee
SEA	Alessandro Fidato
SINTEF	Trond Runar Hagen
Swedavia	Fredrik Jaresved
Thales LAS France	Benjamin Binet
Volocopter	Jörn Jaeger
VTT	Timo Lind

Observer name	Name of main representative
EDA	Emilio Fajardo
Civil users of airspace	Giancarlo Buono
ANSPs (CANSO)	Tanja Grobotek
Equipment manufacturers (ASD)	Vincent de Vroey
Airports (ACI)	Luc Laveyne
Staff association	Marc Baumgartner
Scientific community	
EASA	Patrick Ky
EUROCAE	Christian Schleifer
Unmanned air vehicle industry	Cristiano Baldoni
European Union	**Name of main representative**
European Commission Directorate-General for Mobility and Transport	Henrik Hololei
European Commission Directorate-General for Research and Innovation	Rosalinde Van der Vlies

Annex IX. List of acronyms and definitions

Acronym or abbreviation	Definition
3D	three-dimensional
4D	four-dimensional
AAL2	augmented approaches to land 2
ABAC	accrual-based accounting
ACARE	Advisory Council for Aviation Research and Innovation in Europe
ACC	area control centre
aCCF	algorithmic climate change function
ACI	Airports Council International
ADS-B	automatic dependent surveillance broadcast
ADS-C	automatic dependent surveillance contract
AEON	advanced engine-off navigation
AI	artificial intelligence
AISA	AI Situational Awareness Foundation for Advancing Automation
AMU-LED	air mobility urban – large experimental demonstrations
ANSP	air navigation service provider
AOD	authorising officer by delegation
AOSD	authorising officer by subdelegation
A-PNT	alternative position, navigation and timing
ARES	airspace reservation/ restriction
A-SMGCS	advanced surface movement guidance and control system
ASPRID	airport system protection from intruding drones
ATC	air traffic control
ATCO	air traffic control officer
ATFCM	air traffic flow and capacity management
ATFM	air traffic flow management
ATM	air traffic management

ATN	aeronautical telecommunication network
ATS	air traffic service
ATSU	air traffic system unit
AU	airspace user
B2B	business to business
BADA	base of aircraft data
BEACON	behavioural economics for ATM concepts
CAAR	consolidated annual activity report
CAAS	Civil Aviation Authority of Singapore
CAEP	Committee on Aviation Environmental Protection
CAS	Common Audit Service
CAT	category
CBA	cost–benefit analysis
CDE	communication, dissemination and exploitation
CEF	Connecting Europe Facility
CINEA	European Climate, Infrastructure and Environment Executive Agency
CIRA	Centro Italiano Ricerche Aerospaziali
CIS	common information system
CNS	communications, navigation and surveillance
CO_2	carbon dioxide
ConOps	concept of operations
CORUS-XUAM	concept of operations for European U-space services – extension for urban air mobility
CP1	Common Project One
CTA	controlled time of arrival
DAA	detect and avoid
DCB	demand–capacity balancing
DFS	Deutsche Flugsicherung
DLR	Deutsches Zentrum für Luft- und Raumfahrt

DME	distance measuring equipment
DPIA	data protection impact assessment
DREAMS	demonstration of runway enhanced approaches made with satellite navigation
DSNA	Direction des Services de la Navigation Aérienne
DYNCAT	dynamic configuration adjustment in the TMA
E-AMAN	extended arrivals manager
EASA	European Union Aviation Safety Agency
EASCG	European Air Traffic Management Standards Coordination Group
EASN	European Aeronautics Science Network
EATMA	European air traffic management architecture
ECA	European Court of Auditors
ECAC	European Civil Aviation Conference
ECHO	European concept of higher airspace operations
EDA	European Defence Agency
EDPS	European Data Protection Supervisor
EFTA	European Free Trade Association
EFVS	enhanced flight vision system
EGNOS	European Geostationary Navigation Overlay Service
ENAC	Ecole Nationale de l'Aviation Civile
EOCVM	European operational concept validation methodology
EPP	extended project profile
ER	exploratory research
ESA	European Space Agency
E-TMA	extended terminal manoeuvring area
EUROCAE	European Organisation for Civil Aviation Equipment
EUSCG	European Unmanned Aerial System Standards Coordination Group
FAA	Federal Aviation Administration
FACT	future all-aviation CNS technology

FCI	future communication infrastructure
FIXM	flight information exchange model
FlyATM4E	flying ATM for the benefit of the environment and climate
FMP	flow management position
FMPMet	MET uncertainty management for flow management positions
FO	flight object
FOC	flight operations centre
FP7	seventh framework programme
FTS	fast-time simulation
GANP	global air navigation plan
GAST	ground-based augmentation system approach service type
GBAS	ground-based augmentation system
GNSS	global navigation satellite system
H2020	Horizon 2020
HAAWAII	highly automated air traffic controller workstations with artificial intelligence integration
HMI	human–machine interface
HR	human resources
IA	innovative action
IAC	Internal Audit Capability
IAS	Internal Audit Service
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ICARUS	integrated common altitude reference system for U-space
iCNS	integrated communications, navigation and surveillance
ICT	information and communication technology
IDMS	information and document management service
IEEE	Institute of Electrical and Electronics Engineers
IFR	instrument flight rule

IGS	increased glide slope
IMHOTEP	integrated multimodal airport operations for efficient passenger flow management
INAP	integrated network management ATC planning
IPS	internet protocol suites
IR	industrial research and validation
IRS	interface requirement
IT	information technology
ITACA	incentivising technology adoption for accelerating change in ATM
ITARO	integrated TMA, airport and runway operations
JU	Joint Undertaking
KG	knowledge graph
KPA	key performance area
KPI	key performance indicator
KTN	knowledge transfer network
LDACS	L-band digital aeronautical communications system
MAWP	multiannual work programme
MET	meteorological/meteorology
ML	machine learning
mmW	millimetre wave
MoC	memorandum of cooperation
MPC	Master Planning Committee
NATMIG	North European ATM Industry Group
NM	Network Manager
NSA	national supervisory authority
NWM	numerical weather model
OLAF	European Anti-Fraud Office
OSED	operational services and environment description
PA	performance ambition

PBN	performance-based navigation
PRC	private, for profit company
PSO	professional staff organisation
Q&A	question and answer
QICT	quality information and communication technology
QMS	quality management system
R&D	research and development
R&I	research and innovation
RNP	required navigation performance
RPAS	remotely piloted aircraft system
RTCA	Radio Technical Commission for Aeronautics
RTS	real-time simulation
RWC	remain well clear
SATCOM	satellite communications
SBAS	satellite-based augmentation system
SDM	SESAR Deployment Manager
SDN	software-defined networking
SDSS	SESAR development support services
SEAC	SESAR European Airports Consortium
SecRAM	security risk assessment methodology
SES	single European sky
SESAR	Single European Sky ATM Research
SESAR 3	Single European Sky ATM Research 3
SLA	service-level agreement
SMEs	small and medium-sized enterprises
SNE	seconded national expert
SO_2	sulphur dioxide
SPD	single programming document
SPR(-INTEROP)	safety and performance (and interoperability) requirements

SRAP	second runway aiming point
SRIA	strategic research and innovation agenda
SURF-A	surface traffic alerts on runways for pilots without traffic display and warning alerts only
SURF-ITA	surface traffic alerts and indication on runways for pilots with optional display, caution and warning alerts
SWIM	system-wide information management
TAPAS	towards an automated and explainable ATM system
TBO	trajectory-based operation
TC	thematic challenge
TCAS	traffic collision avoidance system
TINDAIR	tactical instrumental deconfliction and in-flight resolution
TLS	
TMA	terminal manoeuvring area
TRL	technology readiness level
TS	technical specification
TSP	transport service provider
TTA	target time of arrival
U3	U-space advanced
U4	U-space full
UAC	upper area control centre
UAM	urban air mobility
UAS	unmanned aerial system
UDPP	user-driven prioritisation process
UPMS	user profile management system
USEPE	U-space separation in Europe
VHF	very high frequency
VLD	very large-scale demonstration
VSB	virtual stop bar
VTOL	vertical take-off and landing

WP	work package
XAI	explainable artificial intelligence

