A proposal for the future architecture of the European airspace

SESAR
JOINT UNDERTAKING

The proposal outlined in this document was done in collaboration with:

Network Manager
nominated by
the European Commission

EUROCONTROL

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Luxembourg: Publications Office of the European Union, 2019

Print:	ISBN 978-92-9216-116-3	doi:10.2829/718392	catalogue number: MG-03-19-090-EN-C
PDF:	ISBN 978-92-9216-115-6	doi:10.2829/309090	catalogue number: MG-03-19-090-EN-N

Preamble: Towards a Single European Airspace System

When air traffic control centres were first set up within each State, they were built close to the radars or radio antennas, within the line of sight of the flying aircraft. As commercial air traffic grew, the systems used at these centres became more sophisticated thanks to the introduction of electronic assistance technology, and progressive build of flow management capability across European airspace. At the same time, the airspace above the centres was divided into an ever-increasing number of adjacent sectors, so that controllers could manage the aircraft safely at any given time.

The system today still relies on this sectored approach to manage traffic and imposes some limits on the airspace capacity. The airspace is locally optimised according to national needs and preferences, and it is relying mainly on local physical infrastructure. As a result, available capacity in the system is geographically constrained and cannot be activated when and where required to accommodate dynamically the traffic demand. It also means that if one centre has a problem, that problem will inevitably spread. The limits of this architecture were already exposed in the late 1990s.

The Single European Sky initiative was launched with a view to improving the overall performance of air traffic management (ATM) amongst others by moving a number of competences to the framework of the European Union, as part of the Common Transport Policy. New instruments and their legal foundations, such as the Functional Airspace Blocks (FAB), were at that time created as a response to this fragmentation of airspace but in a radically different technology landscape.

The Single European Airspace System proposed in this study is an evolution of the European airspace architecture that leverages modern technologies to decouple the service provision from the local infrastructure. At the same time it increases progressively the level of collaboration and automation support through a data rich and cyber-secured connected ecosystem. Such an evolution opens new business opportunities through creation of a dynamically distributed system, while fully respecting the sovereignty of Member States in relation to their airspace. With this proposal, airspace configuration and design are optimised from a European network point of view, connecting airports and taking due consideration of major traffic flows across Europe. Data services made available to trusted users feed advanced air traffic control tools, allowing operational harmonisation and bringing the level of performance of each control centre to that of today's top 10% -20% performers.

The airspace architecture study proposes a progressive transition strategy towards the Single European Airspace System in three 5 year-periods, while building on known good practices and quick wins, as well as existing initiatives such as SESAR. The aim is to enable progressively additional capacity in order to cope with the significant growth in traffic, while maintaining safety, improving flight efficiency and reducing environmental impact.

- *By 2025, in addition to the already planned roll-out of first SESAR results, new programmes on airspace re-configuration and operational excellence have delivered quick wins. Regulation has evolved to support the transition ahead;*
- *By 2030, the implementation of the next generation of SESAR technologies should be completed with the roll-out of virtualisation techniques and dynamic airspace configuration, supported by the gradual introduction of higher levels of automation support. The new architecture should enable resources (including data) to be shared across the network supporting a flexible and seamless civil/military coordination allowing for more scalable and resilient service delivery to all airspace users;*
- *By 2035, the network should operate at its optimum capability having fully evolved from a system based on punctuality to a system based on predictability across a network that can safely and effectively accommodate 16 million flights (+50% compared to 2017).*

In order to initiate the transition towards a Single European Airspace System, the following three recommendations are made:

- *Launch an airspace re-configuration programme supported by an operational excellence programme to achieve quick wins;*
- *Realise the de-fragmentation of European skies through virtualisation and the free flow of data among trusted users;*
- *Create a legal and financial framework that rewards early movers.*

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Executive summary

In 2017, the European Parliament adopted a resolution on the European Commission's "Aviation Strategy for Europe'. The resolution "*recalls that airspace is also part of the EU single market, and that any fragmentation resulting from its inefficient use, as well as diverging national practices*" causes "*longer flight times, delays, extra fuel burn, and higher levels of CO_2 emissions*". It called on the European Commission to implement the concept of the "*European Upper Flight Information Region (EUIR)*", as an enabler for the gradual establishment of a "*Trans-European Motorway of the Sky*". In this context, the European Parliament invited the European Commission to launch a pilot project on the Single European Sky (SES) airspace architecture.

The European Commission entrusted the SESAR Joint Undertaking in collaboration with the Network Manager with the preparation, launch and management of such a study stressing the need to ensure consistency with the objectives of the SESAR project and in particular, the vision developed in the European ATM Master Plan. This report summarises the results and recommendations of the study.

It is important to note that although the study focused on en-route airspace, dependencies with major flows of traffic in and out of airports were duly considered.

The study re-confirms that without an acceleration of ATM modernisation and complementary changes, the situation of air traffic delays will continue to deteriorate to an unprecedented level

The resumption of strong growth in air traffic is now outpacing the rate of capacity growth and European ATM modernisation. 2018 saw a record 11 million flights, but also severe delays.

Current traffic forecasts indicate sustained traffic growth will continue for the next 17 years. It is estimated that by 2035, there will be an expected 15.7 million flights in the European Civil Aviation Conference (ECAC) region, 5.1 million more than in 2017, or a total increase of 50%. **This creates a major challenge for the ATM industry, which will have to adapt and handle growing traffic safely, efficiently and at an economically acceptable cost.**

Simulations, conducted as part of this study, demonstrate that the capacity crunch that prompted the creation of the SESAR project has returned and highlights the urgent need to accelerate ATM modernisation.

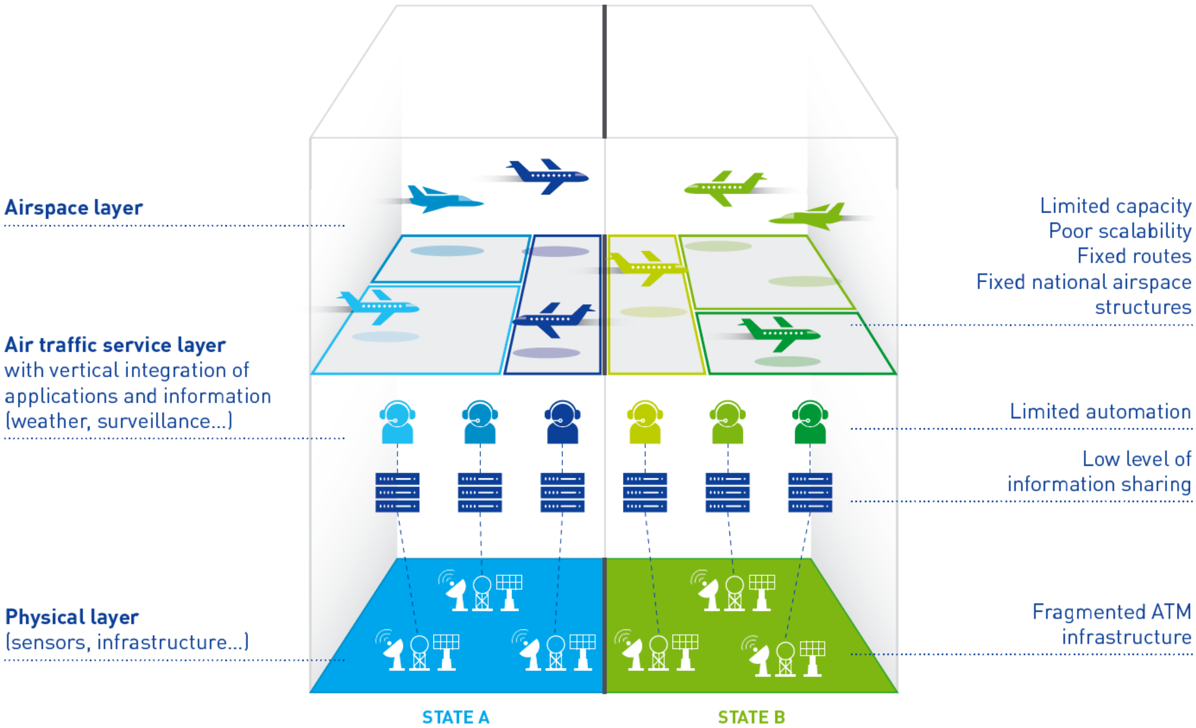
The predicted levels of delays by 2035 are unprecedented and significantly higher than the highest delays ever recorded in the network (5,4 minutes in 1999 during the Kosovo crisis)

Despite the capacity issue, **it is important to emphasise that the performance levels for safety – which is the core business of ATM – have been remarkable** as highlighted in the latest reports by the Performance Review Body (PRB) and the European Aviation Safety Agency (EASA).

This is not a new problem and in the long run it cannot be solved with the same approach as in the past

The current architecture is the result of historical operational and technical evolutions primarily conducted at a national level, which have led to today's fragmented system. Initiatives such as SES and SESAR have led to improved interoperability and harmonisation but have not yet overcome this underlying fragmentation to enable truly seamless airspace operations.

Current architecture



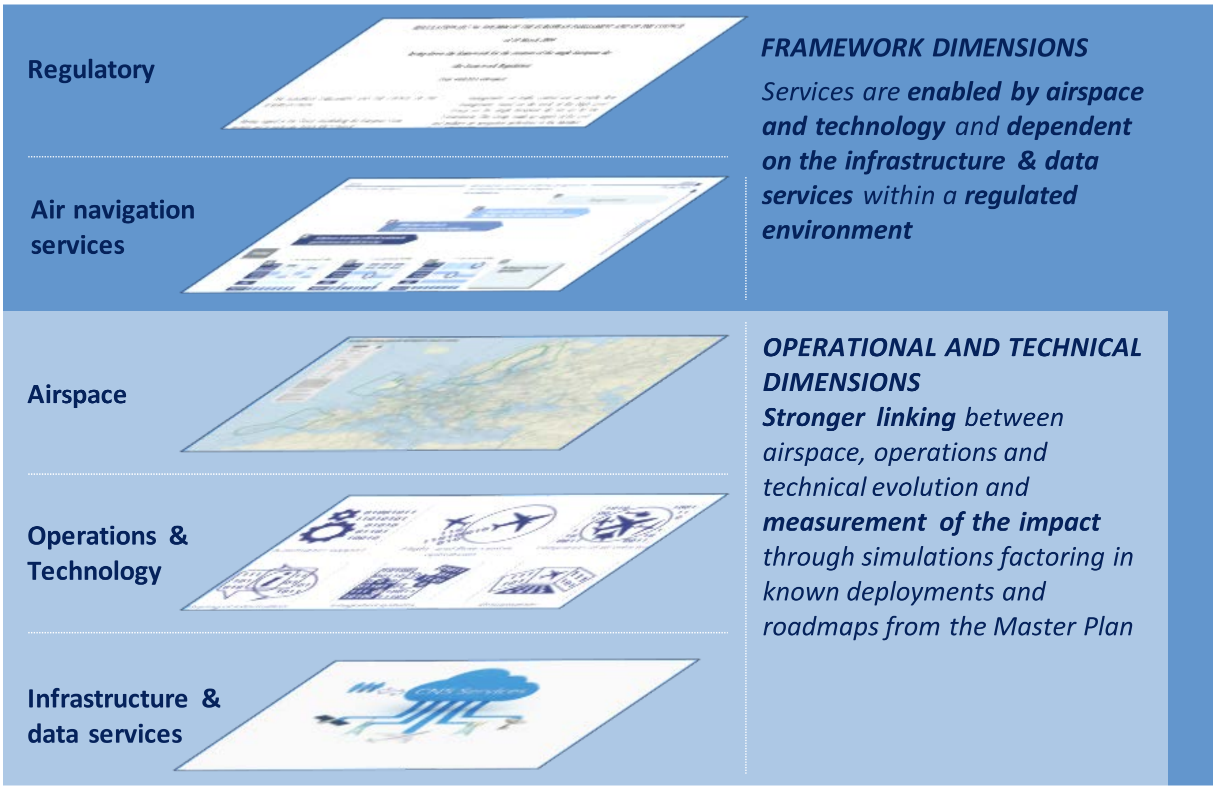
Each area control centre (ACC) is a node in a global network, some of which are already operating very close to maximum capacity. In the current architecture, resources (including data), and therefore the ability to deliver services, are not connected across those nodes. This fundamentally affects how the network behaves today. It means that if one node has a problem, that problem will spread. The network therefore operates with very little leeway. It does not take much to knock it out of optimal flow. Airspace user try to account for all this by building buffers into the schedule. They still encounter delays, and a newly formed delay for one flight can easily propagate to the second and third flights. Part of it may be absorbed by the buffer, but often not all of it.

The factors within the current architecture that limit overall maximum capacity, as well as the scalability and resilience of the system were identified as part of the study. Most of these factors are not new and are already known by the industry. They formed the basis upon which the proposed target architecture was designed.

Factors limiting overall capacity	• Non-optimal organisation of airspace • Limited use of data communications • Limited opportunity to create new sectors • Limited automation support for controllers
Factors limiting capacity scalability and resilience	• Limited predictability • Limited information sharing and interoperability • Limited flexibility in the use of controller resources across ACCs • Geographical constraints on air traffic service provision

The proposed problem-solving approach to build a Single European Airspace System that meets the capacity challenge

The objective of this study is to propose a future airspace architecture, and an associated transition strategy, which is robust enough to ensure the safe, seamless and efficient accommodation of all air traffic by 2035. In doing so, it aims to support the further implementation of the SES. The approach of the study is built around several analytical dimensions as illustrated in the figure below.

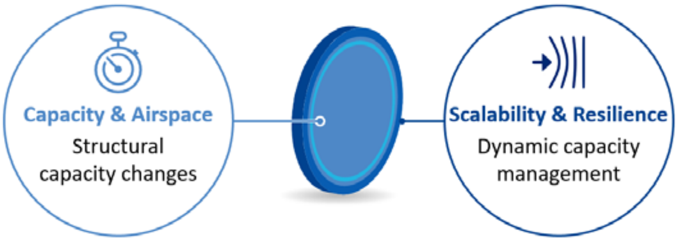


The focus of the study is the link between the operational and technical dimensions – airspace, operations and technology, infrastructure, applications and data services. The intent is to ensure that airspace is optimised according to operational needs, without being dimensioned by FIR or national boundaries. **It is the first time that such a close linking between all these different dimensions has been undertaken in the context of SES.**

In line with the European ATM Master Plan and the wider EU digitalisation agenda, the deployment of SESAR Solutions in the operational and technical dimensions enables more flexibility and robustness in the airspace dimension than is possible using current technology and procedures. **The relationship between SESAR technology and airspace is key to understanding the proposals in this document and relies on the four-phase approach to improvements already identified in the European ATM Master Plan.**

The framework dimensions – service and regulatory – enable the achievement of the proposed architecture. Evolution of these dimensions is closely related to the proposed architecture and the associated potential performance. The study identifies potential issues and implications for these dimensions.

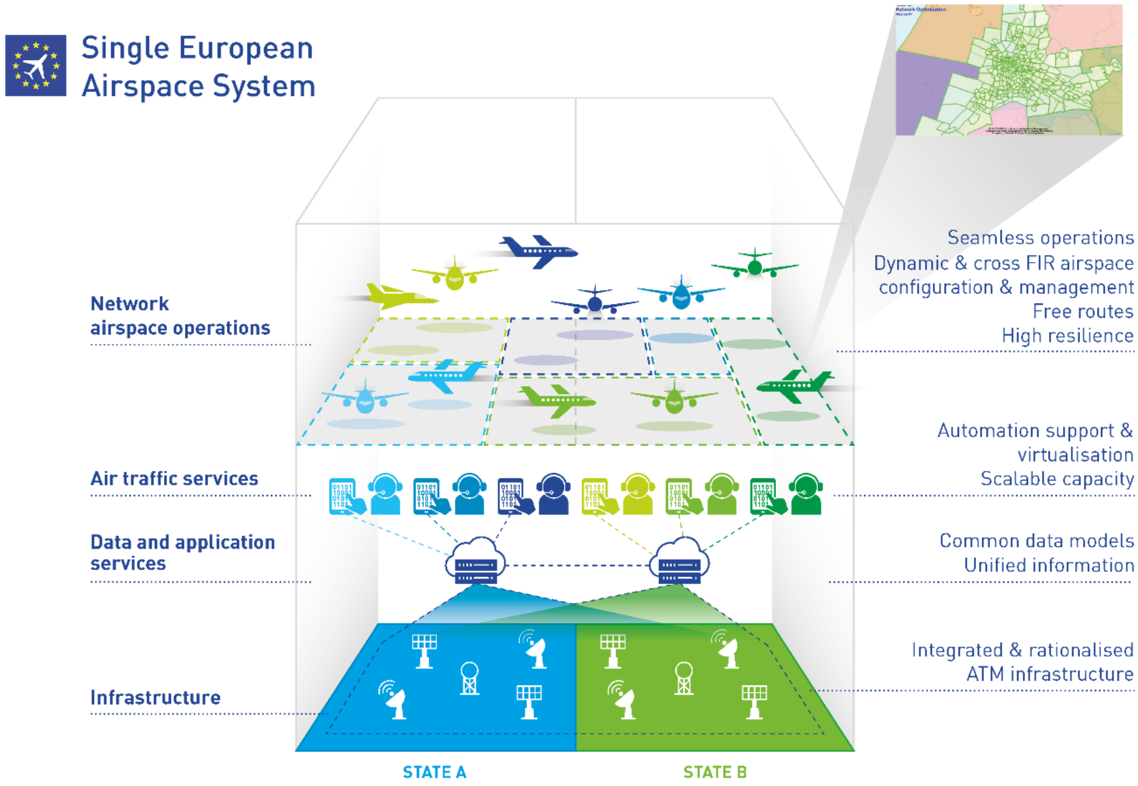
To ensure a clear traceability between the limiting factors presented before and the proposed changes related to the operational and technical dimensions, these solutions have been grouped into two focus areas addressing respectively two side of the same capacity challenge – capacity and airspace, and scalability and resilience - as presented in the figure below.



The proposed Single European Airspace System is built on optimised airspace organisation, supported by progressively higher levels of automation and common ATM data services to deliver seamless air traffic services.

In order to meet the challenges described in the previous section, the progressive implementation of a new architecture is proposed in view of enabling seamless European en-route airspace. This new architecture is captured under the notion of **Single European Airspace System (SEAS)**[1] in which resources are connected and optimised across the network **leveraging modern technology** through a data rich and cyber-secured connected ecosystem. In this environment service providers would be able to collaborate and operate as if they were one organisation with both airspace and service provision optimised according to traffic patterns. This architecture is also more compatible with the overall SESAR vision for a more profound evolution of core air traffic management capabilities driven by new forms of traffic (drones and super-high altitude operations).

[1] By analogy of the National Airspace System (NAS) referred to in the USA



A key enabler for the proposed target architecture is the **optimisation of the airspace organisation across the network supported by operational harmonisation where important quick wins can be achieved**. Furthermore, in order to ensure that in the longer term capacity can keep up with demand it is necessary to decouple airspace from service provision to enable new collaborative approaches for the provision of ATM. This new architecture will:

- Deliver an optimised airspace structure, supported by operational harmonisation;
- Enable ATM capacity and scalability to handle all en-route airspace air traffic safely and efficiently, even according to the highest traffic growth forecast or during traffic growth stagnation or downturn;
- Allow all flights to operate along (or at least as close as possible to) user-preferred routing across the entire airspace;
- Promote an optimal use of ATM resources, reducing current inefficiencies and ATM costs for airspace users (AU) and society;
- Increase the overall resilience of the system to all types of incidents, in terms of safety, efficiency and capacity;
- Continue to facilitate the civil and military access to European airspace.

The solutions underpinning the proposed architecture have been grouped into two focus areas addressing respectively the two core challenges. Both focus areas are part of the transition from today's operational concept to trajectory-based operations as envisaged by Phase C of the European ATM Master Plan.

Focus area 1: **Airspace and capacity**	• **Optimised airspace organisation** – Solutions that support improved design and use of airspace. • **Operational harmonisation** - Aligning the capacity of control centres and ways of working to best practices through systematic operational improvements. • **Automation and productivity tools** – Increased automation as a progressive enabler of trajectory-based operations (TBO) with short, medium and long-term enhancements to provide increased capacity and predictability.	**Trajectory-based operations to address predictability and collaboration -** Deployment of SWIM, 4D trajectory exchange.
Focus area 2: **Scalability and resilience**	• **Virtualisation and ATM data as services** - Transition to virtual centres and a common data layer allowing more flexible provision of ATM services. • **Dynamic management of airspace –** dynamic grouping and de-grouping of sectors and managing the staff resources accordingly. • **Flight-centric operations where applicable** - Changes the responsibility of controller from controlling a piece of airspace to controlling a number of flights along their trajectories. • **Sector-independent ATS operations** - Automation support for controllers to enable provision of ATC without the need for sector specific training and rating. Controller training and licensing to be based on traffic complexity, instead of sector specificities. • **CNS enhancements -** Transition to CNS infrastructure and services concept to support performance based CNS and enable new multi-link air-ground communications environment and continued evolution of the Global Navigation Satellite System (GNSS).	

There are conditions to increase the chances of success and in particular to secure the implementation timeline

The new architecture is designed to enable a shift to a new ATM service delivery landscape. The right conditions need to exist to catalyse a reform of service provision in support of this transition. It is important that existing and potential new service providers are treated in a consistent and equitable manner. There are in particular three conditions that should be considered in order to secure the implementation timeline:

- **Capacity-on-demand** agreements: to ensure the continuity of air traffic services by enabling more dynamically a temporary delegation of the provision of air traffic services to an alternate centre with spare capacity.
- **New model for ATM data service provision**: supporting the progressive shift to a new service delivery model for ATM data, through the establishment of dedicated “ATM data service providers” (ADSPs). The ATM data services provide the data and applications required to provide ATS and include flight data processing functions like flight correlation, trajectory prediction, conflict detection and conflict resolution, and arrival management planning. These services rely on underlying integration services for weather, surveillance and aeronautical information. The maximum scope of service delivery by ADSPs covers the ATM

data services (such as flight data processing) needed to realise the virtual de-fragmentation of European skies and includes the provision of AIS, MET and CNS services.

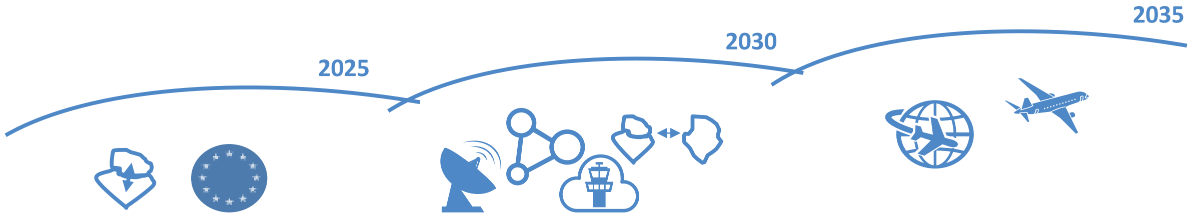
- **Targeted incentives for early movers**: specific incentives should be put in place for those actors that implement recommended operational improvements or that shift towards innovative delivery models with a focus on early movers in order to initiate the transition

A possible way forward by bringing progressive transition every 5 years

A successful transition to the proposed target architecture of a Single European Airspace System will only be possible through collaboration and commitment from all ATM stakeholders. The approach will need to focus on building and maintaining consensus for the transition, including adequate change management and risk management processes and buy-in from all stakeholder groups, including professional staff.

The study does not provide a full transition plan (including detailed actions for each stakeholders) but rather an overall transition strategy together with proposed high-level milestones. The key enabler for achieving the transition to the proposed target architecture is the implementation of common attributes on how to manage airspace in common and a common data layer. Once established, the architecture will allow different parts of the system to develop at different speeds depending on local needs whilst maintaining an overall coherence at network level.

The figure below illustrates the main milestones of each 5-year period during the transition which also **identifies opportunities to realise quick wins** in the areas of airspace re-configuration and operational excellence.



- ECAC-wide implementation of **cross-border Free Route, air-ground** and **ground-ground** connectivity
- Launch **airspace re-configuration** supported by **Operational Excellence** Programme
- Set up an **enabling framework** for **ADSP**, **capacity-on-demand** service and **rewards for early movers**, first ADSP is certified

- Implement **virtual centres** and **dynamic airspace configuration** at large scale
- Gradual transition towards **higher levels of automation** supported by SESAR Solutions
- **Capacity-on-demand** arrangements implemented across Europe
- **New ATM Data service provision model** is implemented across Europe

- Transformation to **flight/flow centric operations**
- **Trajectory-based operations**
- **Service-oriented** air traffic management

Impact assessment

A high level impact assessment was conducted, based on a conservative top-down approach, relying on simulation results from the Network Manager, SESAR validation targets, as well as the overall SESAR performance ambition defined in the European ATM Master Plan to ensure the highest level of consistency.

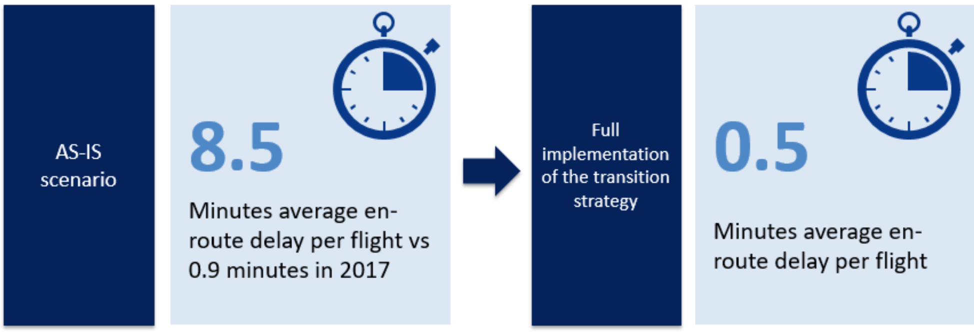
The table below presents the network performance impact covering the proposed target architecture and associated transition strategy for the following SES key performance areas (KPA): capacity, environment, cost efficiency and safety at the 2035 horizon.

KPA	Performance impact (order of magnitude)
Capacity	Network is able to accommodate 15,7 million flights (increase of 50% in Network throughput compared to 2017) with delays below or at the level of the agreed SES target (max 0,5 min per flight distributed across all flights)
Environment	Between 240 and 450 kg of CO2 saved on average per flight due to optimisation of trajectories
Cost Efficiency	Between EUR 57-73 saved per flight due to ANS productivity gains
Safety	All simulations have been done against controller workload and indicate that the same safety levels can be maintained

It is important to note that simulation results taken in isolation show an even more promising potential network performance impact **in particular for quick win measures related to airspace re-configuration and operational excellence at the 2025 horizon**.

In terms of economic impact, the assessment indicates a considerable **net benefits potential of between EUR 31 and EUR 40 billion** (or EUR 13-17 billion in NPV) over the 2019-2035 period taking into account related investment needs. Figures are presented in ranges to take into account uncertainty. A sensitivity analysis was conducted to test the robustness of the CBA results under different assumptions (addressing main areas of uncertainty linked to simulation results, traffic forecasts and investment estimations).

Finally, key simulation results from the Network Manager reflecting an “as-is” scenario for 2035 have been compared with the expected performance gains linked to a full implementation of the transition strategy proposed in the study. As illustrated in the figure below, the full implementation of the transition strategy would bring delays back in line with the SES target (0.5 minutes average en-route delay per flight) while being able to **safely and effectively accommodate 16 million flights** (+50% compared to 2017).



Taken together, the impact assessment results **are sufficient to demonstrate that investing in a solution to the anticipated capacity issues is essential for the future of European aviation**.

Recommendations

In order to initiate the transition towards a **Single European Airspace System**, the following three recommendations should be considered by the European Commission.

Firstly, in addition to the timely roll-out of the first SESAR research and development results (Pilot Common Project) there is a pressing need to implement additional measures covering airspace optimisation and operational harmonisation to contain the current capacity crisis and to maximise benefits of technological evolution.

Recommendation 1: Launch airspace re-configuration supported by an operational excellence programme to achieve quick wins
The Commission is invited to consider the following proposals: • Launch an EU-wide airspace re-configuration programme in which the Member States, the Network Manager, air navigation service providers, civil airspace users and military should work together to define and implement an optimal cross-FIR and flow-centric redesign of airspace sectors. This optimised airspace design should be consistent with already agreed-upon design principles at European level. • Launch an EU-wide operational excellence programme in which the Network Manager, air navigation service providers, civil airspace users, military and staff associations should work together to achieve operational harmonisation aligning on air control centres capacity and ways of working to best practices through systematic operational excellence throughout the Network.

Secondly, this study has demonstrated that increased automation and virtualisation hold the greatest promise for enabling a collaborative approach to ensuring higher levels of resilience. This is an important evolution that operational stakeholders and the supply industry have already been partly anticipating in the SESAR project resulting in the emergence of a number of industry-based alliances (grouping of ANSPs with or without manufacturers) irrespective of national borders or FABs. These forms of cooperation should be encouraged, as they are an effective vehicle to realise the vision of the SES.

Recommendation 2: Realise the de-fragmentation of European skies through virtualisation and the free flow of data among trusted users across borders
The Commission is invited to consider the following proposals: • Review policy options which, on their own or in addition to FABs, could effectively deliver a virtual defragmentation of European skies and potentially generate higher levels of resilience by encouraging industry-based alliances to deliver core interoperability through common service delivery. • Implement a certification and economic framework for ATM data services providers taking also into account possible restructuring of ANSP services as well as an EU framework for on-demand cross-border use of services (capacity-on-demand). • Continue to support the timely delivery of SESAR Solutions contributing to the delivery of the proposed target architecture.

Thirdly, based on the analysis conducted in this study, we concluded that certain refinements are necessary to encourage early movers and promote the shift of operational stakeholders towards a service-oriented model supporting true harmonisation of operational concepts and supporting technologies across borders.

Recommendation 3: Create a legal and financial framework that rewards early movers
The Commission is invited to consider reviewing the incentivisation policy to reward actors who are the first to implement the high-level milestones identified in the proposed transition strategy.

1 Introduction

1.1 Study context

In 2017, the European Parliament adopted a resolution[2] on the European Commission (EC) communication of 7 December 2015 entitled 'An Aviation Strategy for Europe'. The resolution "*recalls that airspace is also part of the EU single market, and that any fragmentation resulting from its inefficient use, as well as diverging national practices*" causes "*longer flight times, delays, extra fuel burn, and higher levels of CO_2 emissions*". It calls as well on the European Commission to implement the concept of the "*European Upper Flight Information Region (EUIR)*", as an enabler for the gradual establishment of a "*Trans-European Motorway of the Sky*". In this context, the European Parliament invited[3] the European Commission to launch a pilot project on the Single European Sky (SES) airspace architecture (this study).

Later in 2017, the European Commission entrusted[4] the SESAR Joint Undertaking in collaboration with the Network Manager with the preparation, launch and management of such a study stressing the need to ensure consistency with the objectives of the SESAR project and in particular, the vision developed in the European ATM Master Plan[5].

1.2 Objective

The objective of the airspace architecture study (AAS) is to develop a proposal for the future architecture of the European airspace, which can be achieved by 2035.

In proposing a new architecture, the study takes into account SESAR-related operational concepts and technologies (SESAR Solutions) to provide an overall framework capable of supporting the SES vision and the associated high-level goals in terms of safety, capacity, environmental impact and flight efficiency.

This new architecture will improve capacity, efficiency and connectivity, consequently addressing the limits to growth in the air. By strengthening the risk and performance-based mind-set, the study proposals seek to address the key priorities of the 'Aviation Strategy for Europe', while maintaining EU's high standards in terms of safety and security.

1.3 Study approach and scope

The analytical approach of the study is built around the five analytical dimensions illustrated in Figure 1. The study focuses on the operational and technical dimensions – Airspace, operations and technology, and infrastructure and data services – proposing a new architecture that aims to

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[2] European Parliament resolution on an Aviation Strategy for Europe (2016/2062(INI)), February 16th 2017

[3] Request of the European Parliament (MEP Marinescu): "The pilot project would evaluate a new design for the EU airspace architecture based only on traffic flow efficiency, direct routes, and the most efficient number of control centres. This proposal should take into account SESAR-related technology in order to assure the most efficient deployment locations"

[4] Delegation Agreement MOVE/E3/DA/2017-477/S12.766828

[5] European ATM Master Plan Edition 2015, section 2: "The SESAR Vison"

optimise the airspace operational needs and without undue regard for flight information regions (FIRs) or national boundaries. It is the first time that such a close coupling between technology and airspace has been undertaken in the context of the SESAR.

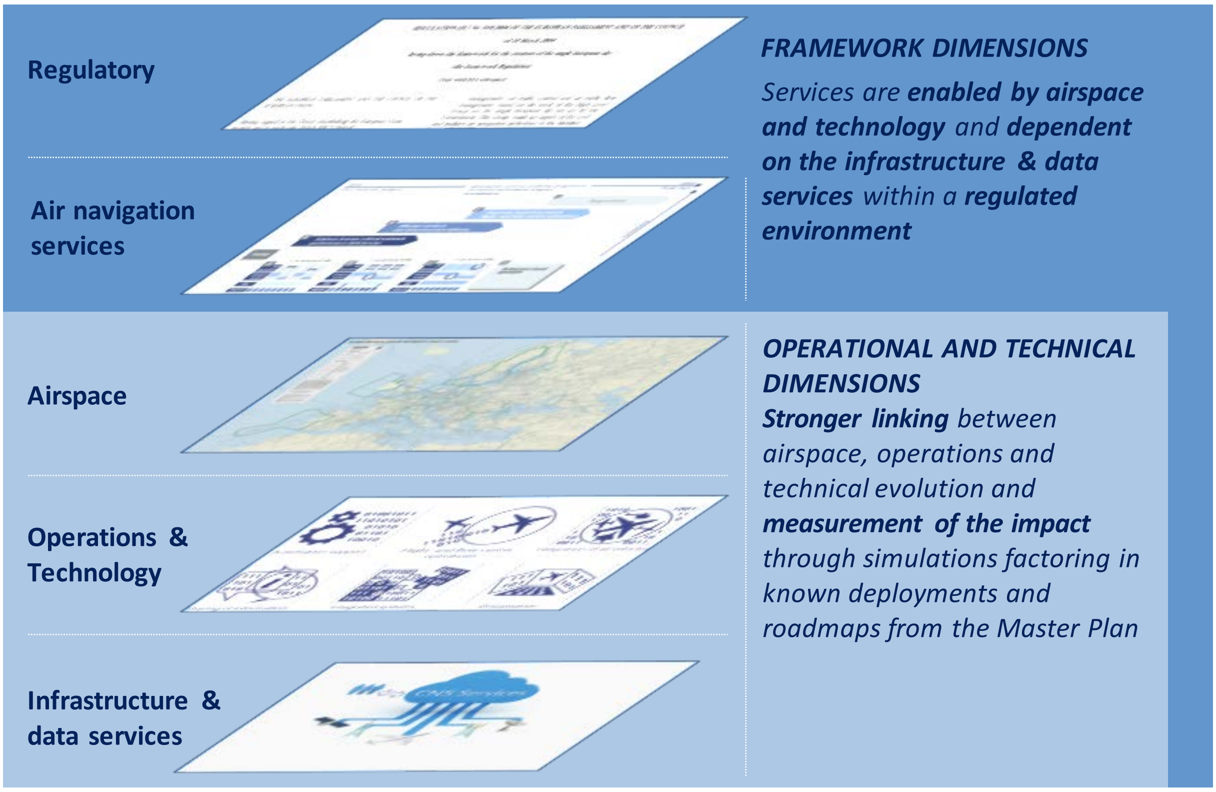

Figure 1. Analytical approach for the study[6]

The proposed target architecture, which is in line with the European ATM Master Plan, the Aviation Strategy and the wider EU digitalisation agenda, is based on the deployment of SESAR Solutions in the "operations and technology dimension" and "infrastructure and data services dimension" to enable more flexibility and robustness in the airspace dimension.

The relationship between the SESAR operational technical solutions and airspace design is key to understanding the study's proposals. The proposed target architecture is consistent with phase C of the European ATM Masterplan (see Figure 2).

[6] Source: SJU analysis, 2018

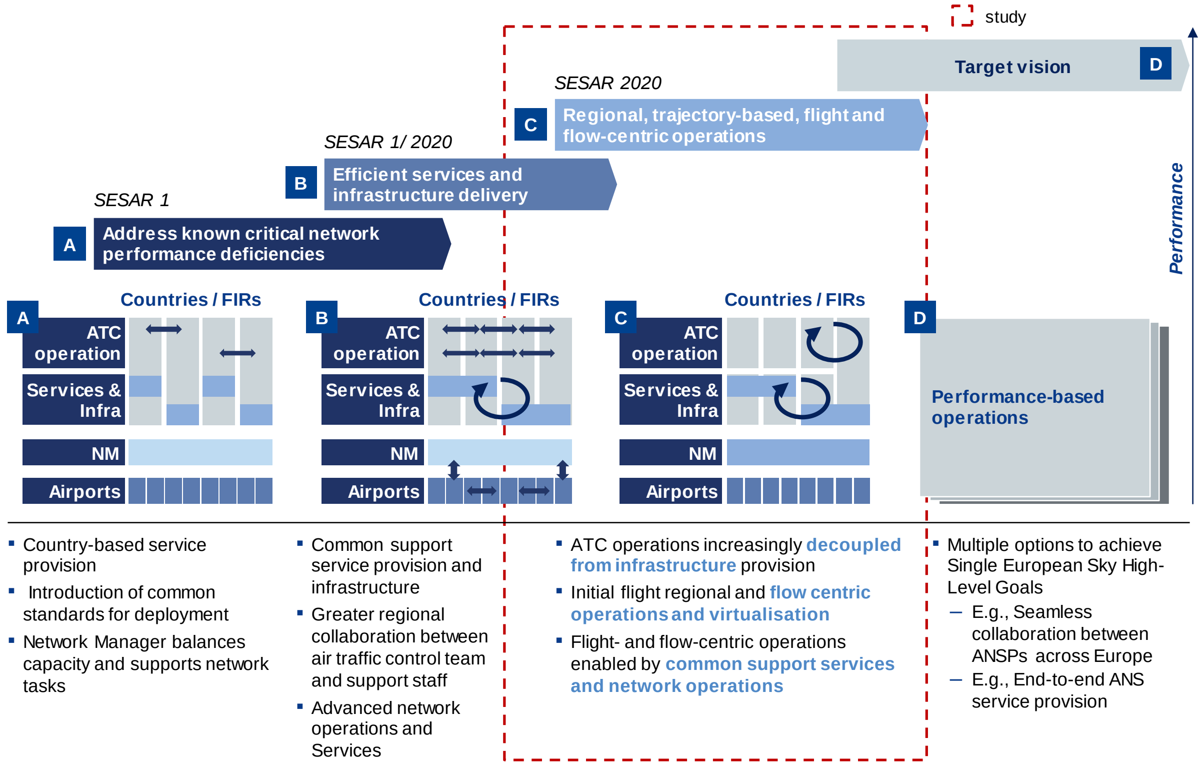

Figure 2. Link between the European ATM Master Plan (2015 edition) and the Airspace Architecture Study[7]

The framework dimensions – "regulatory" and "air navigation service" – enable the achievement of the proposed target architecture. The study identifies potential issues and implications for these dimensions.

1.3.1 Consultation

In addition to two open workshops hosted by the European Commission in July and November 2018[8], the SJU conducted rounds of bilateral meetings (in May and October 2018) with stakeholder representative organisations listed in Table 1.

A6 Alliance	The Aircraft Owners and Pilots Association	Airlines for Europe
Borealis Alliance	CANSO	COOPANS
European Aviation Safety Agency (EASA)	European Business Aviation Association	European Helicopter Association
European Defence Agency	SESAR Partners	Gate One Partners
IATA	Aerospace and Defence Industries Association of Europe (ASD)	
National Supervisory Authorities	Professional Staff Organisations	SESAR Deployment Manager

Table 1. Stakeholders consulted during the bilateral meetings

[7] Source: European ATM Master Plan Ed. 2015, https://www.atmmasterplan.eu/
[8] https://www.sesarju.eu/events/architecture_study_workshop and https://www.sesarju.eu/node/3080

1.3.2 Study scope

In performing the study, a number of choices were made to scope and define the work:

- The geographical scope of the study was defined as the 44 Member States of European Civil Aviation Conference (ECAC) and Morocco. This is consistent with the scope of the European ATM Master Plan.
- The study focussed on capacity, scalability and resilience of the system in order to ensure that the European ATM system can evolve to support the expected demand.
- The creation of a European Upper Information Region (EUIR) was considered as a potential regulatory enabler amongst other alternative or complementary options.
- The proposed target architecture should be scalable; the actual number of centres and operational units required was not considered within the study.
- The study is not intended as an alternative to the European ATM Master Plan, rather it is consistent with the Master Plan's vision and is based on a more specific analysis combining airspace and relevant SESAR Solutions.

1.3.3 Terminal and airport capacity

This study considered upper en-route airspace. In proposing a new organisation for the upper airspace, connectivity between en-route and terminal airspace was taken into account. It is noted that a reduction of delays and increase of predictability in en-route airspace will have a positive effect on gate to gate predictability and of terminal airspace and airport capacity.

However, increasing en-route capacity will not on its own resolve airport capacity problems of congested airports. With the overall increase of air traffic used as the starting point for this study, congestion at airports and their corresponding terminal airspace will increase. The European ATM Master Plan includes initiatives not considered in this study that will increase gate-to-gate capacity including airport capacity.

1.3.4 Limits of the analysis performed

It is recognised that a study of this nature is high level and provides an initial implementation strategy. Detailed work is now needed to build consensus on the technical details of the proposed target architecture and how best to achieve the transition.

The study has the following limits in terms of scope and depth:

- The study does not address all capacity issues as the scope of the study is limited to en-route European airspace. Nevertheless, connectivity between en-route and terminal airspace have been taken into account in the simulations and airspace proposals. As already foreseen in the European ATM Master Plan, other initiatives are required to increase gate-to-gate capacity including resolving issues with airport capacity.

- The study has a 2035 horizon, considering operational and technical concepts and the progress in their delivery (considering different levels of maturity). The simulations and the impact assessment are therefore based on high-level assumptions that must be further validated as concepts mature.
- The reports touches qualitatively upon policy dimensions like performance, safety, cybersecurity, environment, military and governance. However, the simulations and high-level impact assessment primarily focus on quantification of capacity, cost efficiency and environment. They do not provide a full view of the social implications nor of any State-specific impacts.
- The fast-time simulations, which were conducted by the Network Manager to support the study, are based on a high-level re-design of what would be achievable following the timely implementation of the first SESAR R&D results and operational harmonisation. The simulations do not distinguish between performance gains from airspace re-configuration and operational harmonisation.
- The fast-time simulations integrating advanced SESAR Solutions are based on expert judgement of improvements to air traffic controller workload, which have not for all of them yet been subject to validation through real-time simulations. Similarly, the impact assessment is a high-level assessment based on the available data and high-level assumptions consistent with the European ATM Master Plan.
- The study is of a technical nature – it proposes a target architecture. It is recognised that its successful implementation may require changes to the regulatory framework, to be considered by the European Commission and further detailed thereafter.
- While recognising the importance of different types of airspace users, the study focussed on the flexibility required to support all airspace users rather than the detailed specificities for different categories of vehicles, such as drones or business aviation operating in en-route airspace.
- Benchmarking with other regions in the world was excluded from the scope of the study.
- The proposed transition strategy is high level; it does not describe a full roll-out plan, detailing all steps recommended to be undertaken by stakeholders and associated governance. Issues related to regulatory aspects (such as certification, liability, competition and data access) are identified but will require further analysis as the regulatory framework evolves.

1.4 Report Structure

The remainder of this report is structured as follows:

- *Section 2 – Performance overview:* provides overview of historical, current and predicted performance of the ATM system, taking into account current deployment activities. The analysis re-confirms that if significant changes are not made then the situation will continue to deteriorate with delays of an unprecedented level.
- *Section 3 – Factors limiting airspace capacity:* outlines the factors limiting capacity, noting that this not new problem and in the long run cannot be solved with the same approach as in the past.

- *Section 4 – Proposed target architecture:* describes the target architecture (airspace, operational and technical dimensions), specifying that the proposed future airspace architecture relies on optimised airspace organisation, supported by progressively higher levels of automation and common ATM data services.
- *Section 5 – Conditions for success:* highlights the conditions necessary in order to increase the chances of success and in particular to secure the transition (framework dimensions).
- *Section 6 – Transition strategy:* describes the proposed transition strategy, including risk management, with a possible way forward by bringing progressive transition every 5 years.
- *Section 7 – High-level impact assessment:* outlines the high-level impact assessment and demonstrates that investing in the proposed target architecture to structurally address the capacity, resilience and scalability issues is essential for the future of European aviation.
- *Section 8 – Recommendations:* proposes a set of recommendations to initiate the transition process.

The report is complemented by the following supporting annexes:

- *Annex A – Glossary:* definitions of terms and acronyms used in the study.
- *Annex B – Key reference documents:* lists the references used during the study.
- *Annex C – Network manager simulations:* description of the approach, assumptions and results of the Network Manager simulations.
- *Annex D – Detailed description of the target service architecture:* detailed description of the proposed target architecture.
- *Annex E – SESAR Solutions underpinning the study:* detailed mapping of the contribution of SESAR Solutions to achieving the proposed target architecture.
- *Annex F – Regulatory analysis:* detailed analysis of the current regulatory framework and the impact of the proposed target architecture.
- *Annex G – Impact assessment:* details the impact assessment building on the outcomes of the simulations performed by the Network Manager.

2 Performance Overview

2.1 Historical performance

Figure 3 illustrates the evolution of traffic and delay between 1990 and 2017. During this period, European air traffic increased by 31.7% in terms of movements, representing an average increase of 1.55% per year[9]. However, this hides significant variations in traffic growth over the period. Following robust growth between 1999 and 2007, the 2008 economic crisis produced a sharp decrease in traffic. Traffic then stagnated until 2013 after which growth started to pick up to reach a total of 10.6 million flights in 2017.

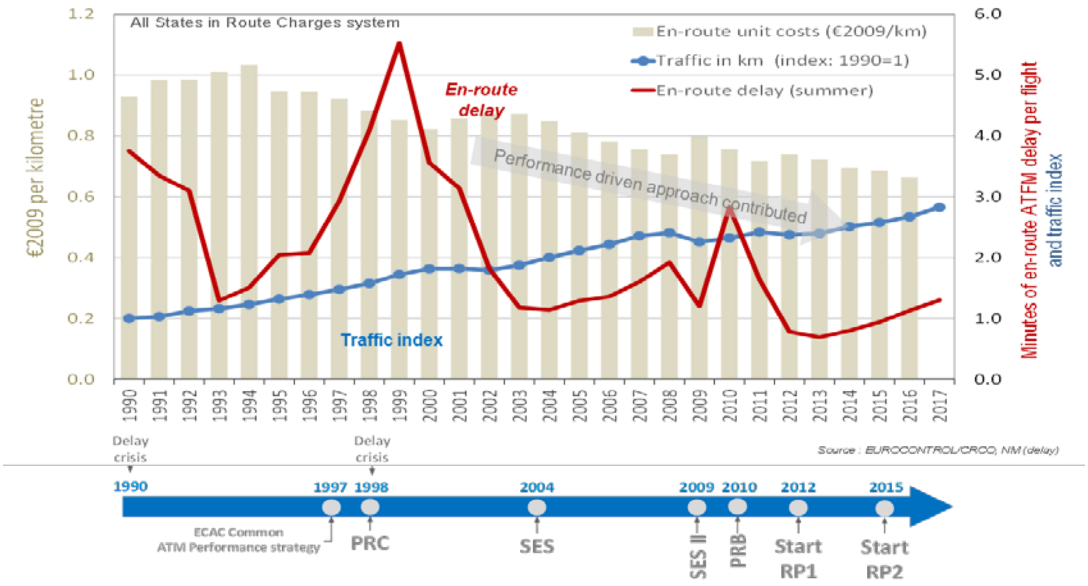

Figure 3. IFR traffic growth evolution and delays 1999-2017[10]

Delay performance has also varied over the years. At the end of the 1990s, the ECAC region was characterised by high levels of delays across the network, averaging 5.5 minutes of en-route delay per flight in 1999. The situation improved over the following 6 years, with average delays reaching a low of 0.86 minutes per flight by 2004. This improvement can be attributed to a series of measures at all levels including for example the:

- Implementation of reduced vertical separation minima (RVSM) resulting in the reduction of the standard vertical separation required between aircraft flying between FL290 (29,000 ft) and FL410 (41,000 ft) inclusively. This increased the number of aircraft that can safely fly in a particular volume of airspace.

[9] Performance Review Report 2015, PRR2015, Performance Review Commission, Eurocontrol, June 2016
[10] Source Eurocontrol, Central Route Charges Office, 2018

- Introduction of en-route support tools, such as automatic coordination and short-term conflict alerts (STCA) to assist the controller in preventing collision between aircraft by generating an alert of a potential or actual infringement of separation minima.
- Introduction of the Central Flow Management Unit (CFMU) in 1995 at Eurocontrol to improve the balancing of demand and capacity.
- Basic RNAV became mandatory in European airspace in April 1998
- Air-ground communications using VHF 8.33 kHz channel spacing were introduced in European airspace to alleviate VHF congestion. In 1999, 30 States within the ICAO EUR region enforced mandatory carriage of 8.33 kHz radios above FL245.

However, after 2004 increases in network capacity were not sufficient to meet the strong growth in demand that followed, so that delays began to rise again, back to approximately 1.6 minutes per flight in 2008. This was taken in due account when launching the SESAR development phase. After a temporary improvement resulting from the 2009 decrease in traffic, significant capacity reduction sent the average delay back up to 2.02 minutes in 2010. Subsequent catch-up in capacity mostly due to improvements in airspace structure, sectorisation, ATM systems modernisation, staffing/rostering policy within ANSPs and ATFM optimisation[11], together with low traffic growth over the period, resulted in rapid improvement over the next 4 years, with delays dropping to a record low of 0.53 minutes in 2013. Since then the capacity target has not been met as depicted below in Figure 4.

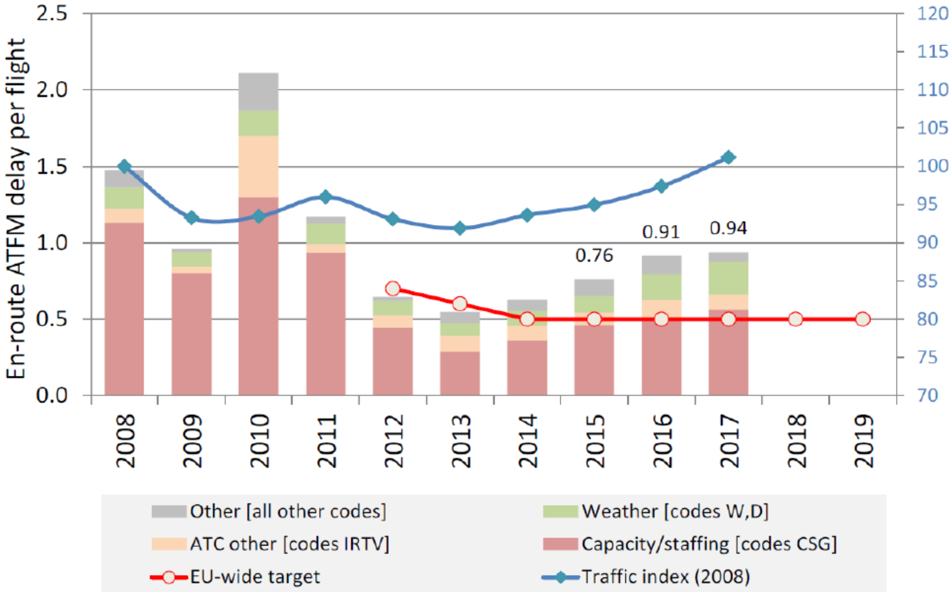

Figure 4. Historic average en-route delay evolution[12]

Despite these capacity issues, it is important to emphasise that performance levels in terms of safety – which is the core business of ATM – have been remarkable as highlighted in the latest reports[13] by the Performance Review Body (PRB) and EASA.

[11] Performance Review Report (PRR 2013)

[12] Source: PRB Annual Monitoring Report 2017

2.2 Current performance

Since 2013, the delivered capacity increases have not been able to match the 3% average increase in traffic leading to increased delays. Strategic recruitment choices, unexpected shifts in demand and sub-optimal deployment of staff in some area control centres (ACCs) has led to opening of fewer sectors than planned in the network operations plan (NOP)[14] and as a result no effective mitigation action has been possible. Network disruption due to industrial actions and weather has also increased in the last five years. These unaddressed structural and tactical issues have resulted in the very difficult summer season in 2018, characterised by extreme delays. As a result, issues with the performance of European ATM has reached the wider public increasing the pressure on all stakeholders to take urgent action to identify the underlying causes for these delays and to implement solutions.

In 2018, there was an all-time record of 11,011,434 flights in the network, an increase of 3.8% compared to 2017. En-route air traffic flow management (ATFM) delay was 1.73 minutes per flight compared with the EU-wide performance target for the year of 0.5 minutes. It is double the 2017 figure and results in a total of 19.1 million minutes of delay. Airport ATFM delay has decreased 3% to 0.6 minutes per flight. The combination of high levels of demand with a major drop in capacity in two centres in the core area of European airspace and a record number of adverse weather events and industrial actions severely disrupted the network in 2018. The staffing situation was the top delay contributor to the network but was known ahead of the summer and mitigation plans were implemented aimed at reducing demand in the affected sector (NM/4ACC initiative). In other areas, the high number of industrial actions, the failure to deliver the NOP capacity and other staffing issues also had a significant impact on the network. The frequent changes to ATFM regulations contributed to calculated take-off time (CTOT) volatility and some airports often struggling to maintain a stable departure sequence in summer. This is illustrated[15] in Figure 5.

Despite the disruptions mentioned above, overall flight efficiency performance indicators remained stable. The route extension indicator based on the last filed flight plan (KEP) decreased to 4.72%, the best since 2014, but still off-target by 0.45% for the SES area. The actual trajectory indicator (KEA) was 2.83%, slightly off-target (0.14% above target for the SES area).

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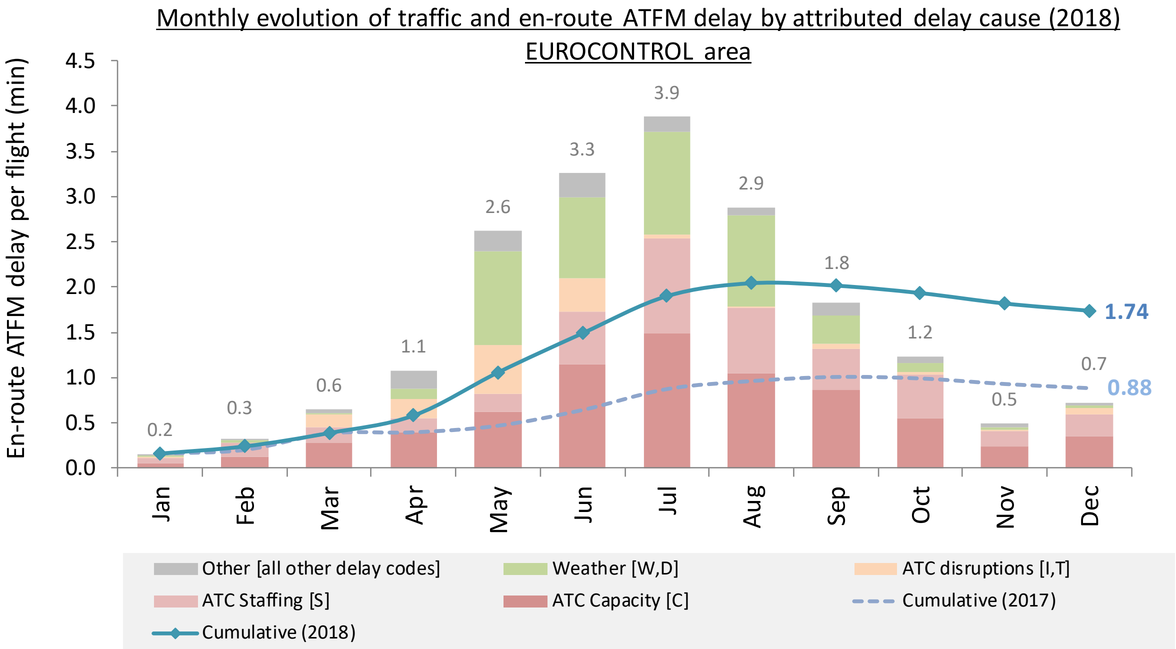
[13] PRB Annual Monitoring Report 2017, EASA 2017 Safety Report Volume 3

[14] European Network Operations Plan 2018-2019/22 (Available at: https://www.eurocontrol.int/publications/european-network-operations-plan-2018-2022)

[15] All-Causes Delay to Air Transport in Europe August 2018 , Network Manager, September 2018) (Available at: https://www.eurocontrol.int/sites/default/files/publication/files/flad-august-2018.pdf)



Source: EUROCONTROL, Performance Review Unit

Figure 5. Monthly evolution of traffic and en-route ATFM delay-by-delay cause[16]

2.3 Predicted future performance

Current traffic forecasts are predicting that the return to a period of sustained growth will continue. As illustrated in Figure 6, the latest long-term traffic growth scenario[17] from Eurocontrol's statistics and forecasts service (STATFOR) predicts significant growth over the next 17 years. This leads to an expected total of 15.2 million flights by 2035 in the ECAC region, 4.6 million more than in 2017, or a total increase of 43%.

In generating the forecast, STATFOR observed that the following industry trends are new and therefore underrepresented in the forecast methodology making the high "global growth" scenario more credible than in the past[18]:

- Low-cost carriers are increasing their presence in the long-haul flights segment, driving up overall air traffic activity.
- The disposable income of the Chinese population is steadily rising, leading to an increase in spending on discretionary purchases such as tourism.
- Additional air travel demand will be unlocked through several new airports and additional runways across Europe.

[16] Source: Eurocontrol/ Performance review unit, 2018
[17] European Aviation in 2040 Challenges of growth Annex1 Flight Forecast to 2040, Eurocontrol. (Available at: https://www.eurocontrol.int/publications/flight-forecast-2040-challenges-growth-annex-1)
[18] Page 3-6 of [18] European Aviation in 2040 Challenges of growth Annex1 Flight Forecast to 2040, Eurocontrol. (Available at: https://www.eurocontrol.int/publications/flight-forecast-2040-challenges-growth-annex-1)

STATFOR's high-growth scenario predicts an average growth rate of 2.7% for 2018–35, leading to an expected total number of 17.3 million flights by 2035, 6.7 million more than in 2017, or a total increase of 64%.

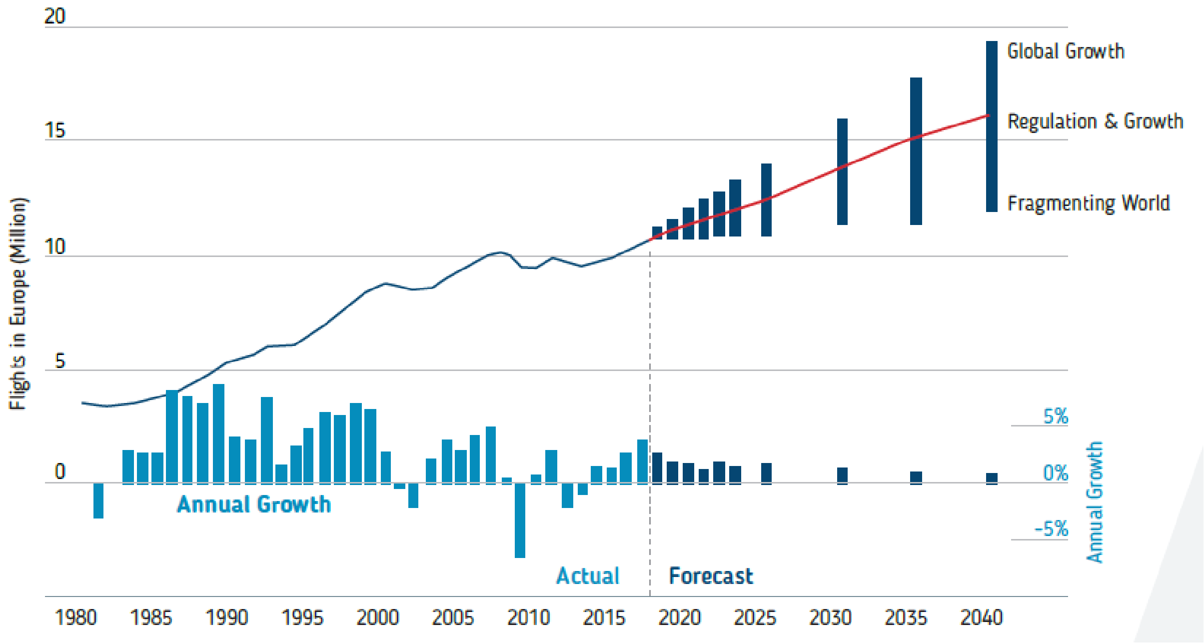


Figure 6. STATFOR Long-term traffic forecast[19]

These developments create a major challenge for the ATM industry, which will have to adapt to them and handle them safely, efficiently, environmentally and at an economically acceptable cost.

Figure 7 illustrates the results of a simulation performed by the Network Manager in the context of this study at the 2035 horizon (see Annex C) using the following assumptions:

- The traffic used for the simulations was based on a typical 2016 summer day and adjusted according to the high traffic growth forecast for future scenarios;
- The simulations were based on the current airspace design, with further optimisation limited to those improvements that are already approved in the Network Operations Plan (NOP)[20];
- The sector capacity is based on the area control centres (ACCs) plans in the NOP until 2022, plus a projection based on typical annual capacity increases for 2022 to 2035;
- The simulations assume a timely deployment of the Pilot Common Project (PCP).

[19] Source: European Aviation in 2040 challenges of growth Annex1 Flight Forecast to 2040, Eurocontrol. (Available at: https://www.eurocontrol.int/publications/flight-forecast-2040-challenges-growth-annex-1)
[20] European Network Operations Plan 2018-2019/22 (Available at: https://www.eurocontrol.int/publications/european-network-operations-plan-2018-2022)

The predicted levels of delays are unprecedented and significantly higher than the highest annual delay ever recorded in the network (5.4 minutes in 1999 during the Kosovo crisis).

Figure 7. Key simulation results reflecting the "as-is" scenario at 2035 horizon[21]

[21] Source: Network Manager simulation performed in the context of this study, 2018

3 Factors limiting airspace capacity

This section provides a brief overview of the current European ATM system and the main factors that limit airspace capacity.

Section 3.1 describes the current organisation of ATM in Europe and the typical architecture deployed within air navigation service providers (ANSP). Understanding the baseline architecture will make it easier for the reader to understand the changes proposed in the target architecture, as described in Section 4.

Sections 3.2 and 3.3 define the main factors that limit overall capacity and the use of that capacity due to limited scalability and resilience.

The intent is not to present an exhaustive analysis but rather to highlight the main factors currently limiting capacity that could be resolved through the adoption of a new architecture and in particular the opportunity of bringing innovative solutions by combining airspace and technology improvements.

3.1 Current organisation of ATM

3.1.1 Introduction

The current architecture is the result of historical operational and technical evolutions primarily conducted on a national basis and leading to an overall fragmented system. Initiatives such as SES and SESAR have led to improved interoperability and harmonisation but have not yet overcome this underlying fragmentation to enable truly seamless airspace operations.

In the current architecture, aircraft operations are often restricted by non-operational airspace boundaries, leading to sub-optimal flight trajectories.

Air navigation service providers (ANSPs) control airspace that is largely based on national boundaries. Each State's airspace is organised as one or more flight information regions (FIRs), each with a dedicated area control centre (ACC). ACCs are divided into adjacent airspace sectors and sector groups. Controllers are typically trained and certified for a limited set of the sectors within an ACC.

Each ACC has a tightly integrated flight data processing system that provides the controller working position with processed local flight information, weather, surveillance and aeronautical information in support of traffic planning, separation, conflict detection and safety nets. These flight data processing systems are typically based on a limited level of automation. The human plays a major role in planning and executing conflict detection and conflict resolution tasks.

Current architecture

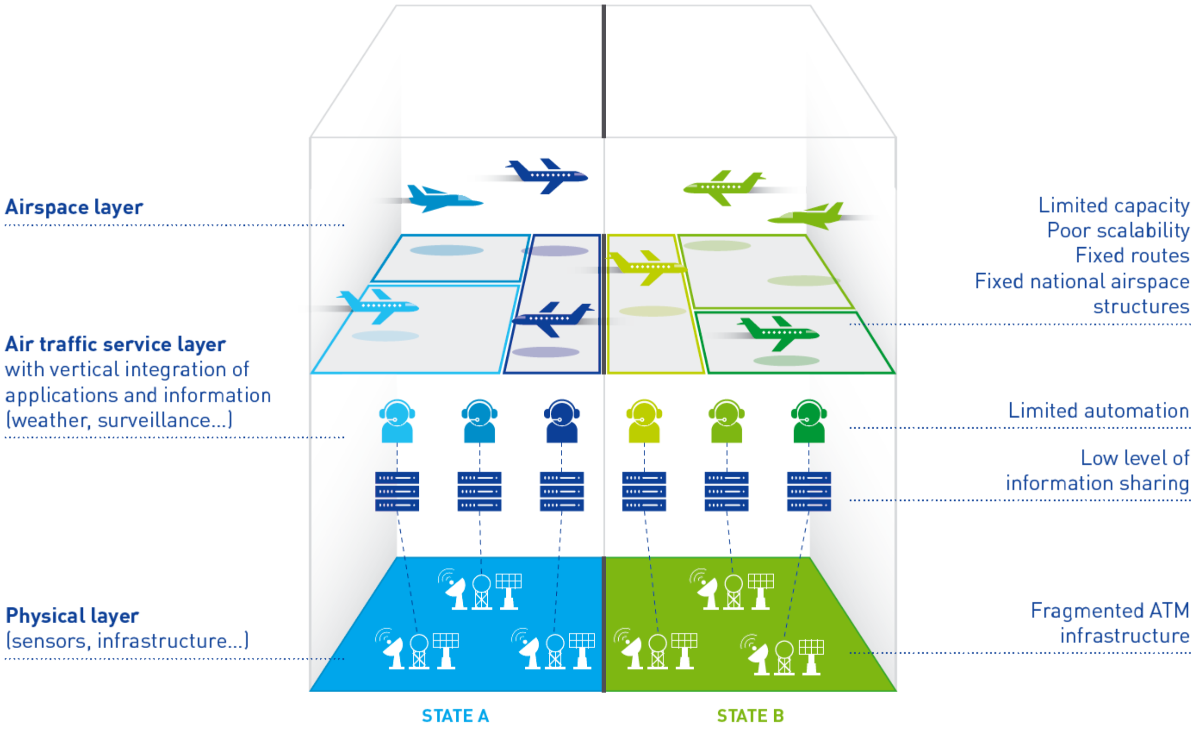


Figure 8 Current Architecture[22]

Each ACC operates its own local physical layer that includes CNS and MET sensors, and ground-ground communications for connectivity with neighbouring ACCs, network manager, airports. However, Information sharing with these actors is limited. Consequently, any operational actor outside the ACC has a limited situation awareness of any changes on the flight trajectory imposed by the air traffic control within that ACC.

Due to the limitations on flexibility for routing, flexibility for allocation of controllers, and the fragmentation of the underlying ATM infrastructure, the ATM system as a whole has poor scalability and is limited in its capacity to provide air traffic services at the right time (including peak times), in the right place.

[22] Source: SESAR JU, 2019

3.1.2 Provision of en-route ATM

Figure 9 represents an architectural view[23] of the main ATM business functions that are under the responsibilities of the four main ATM stakeholders: ANSPs, Network Manager (NM), airport operators (APT) and airspace users (AU).

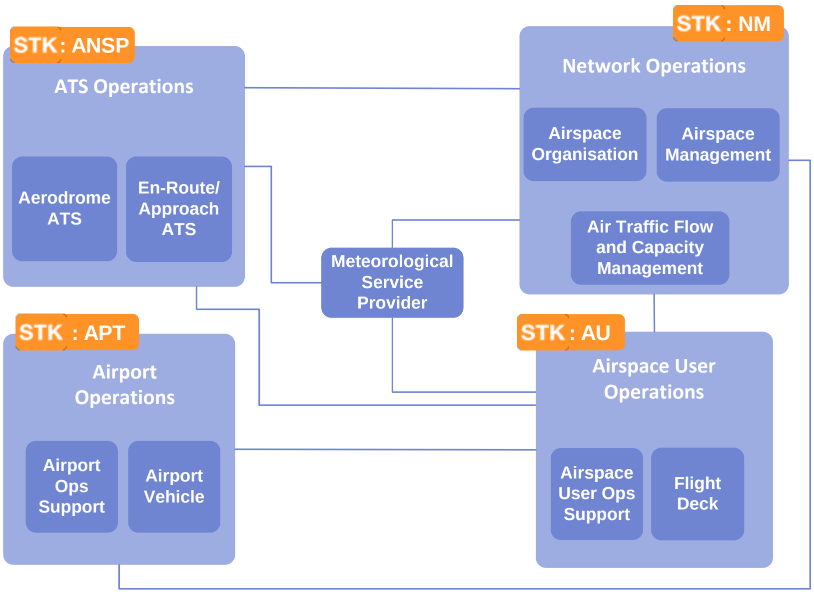


Figure 9. The main ATM Business functions today[24]

Across Europe, en-route ATM is provided by national ANSP operating one or more ACCs[25]. In terms of physical locations, the ATM system consists of:

- 63 en-route ACC and/or UAC[26], each of which is responsible for providing ATM services for a portion of the airspace.
- 262 approach services collocated with ACCs or tower facilities and 16 stand-alone approach centres.
- 415 airports with aerodrome air traffic services (ATS).

In addition, the Network Manager (assigned to Eurocontrol) executes ATM network functions including Air Traffic Flow Management.

[23] Derived from EATMA available at: https://www.atmmasterplan.eu/rnd/operational-nodes-overview

[24] Source: SESAR's European ATM architecture (EATMA) , 2018

[25] Apart from the Maastricht Upper Area Control Centre (UAC), which is an international air navigation service provider operated by Eurocontrol on behalf of Belgium, Germany, Luxemburg and The Netherlands. It maintains air traffic control in the upper airspace (above 24 500 feet or 7.5 km) over Benelux and North West Germany

[26] The term ACC will be used as a generic term for ACC and UAC

3.1.3 Current Architecture

Historically, the European ATM system architecture (see Figure 10) is a collection of bespoke systems, operated by ANSPs and supplied by different industry manufacturers, with slightly different sets of rules and procedures. The level of interoperability between these systems is low with most interactions based on legacy exchanges. As part of the SES initiative, a number of implementing rules have been developed that increase connectivity between ACC flight data systems (such as OLDI) as well as the common use of ARTAS and ASTERIX for surveillance data.

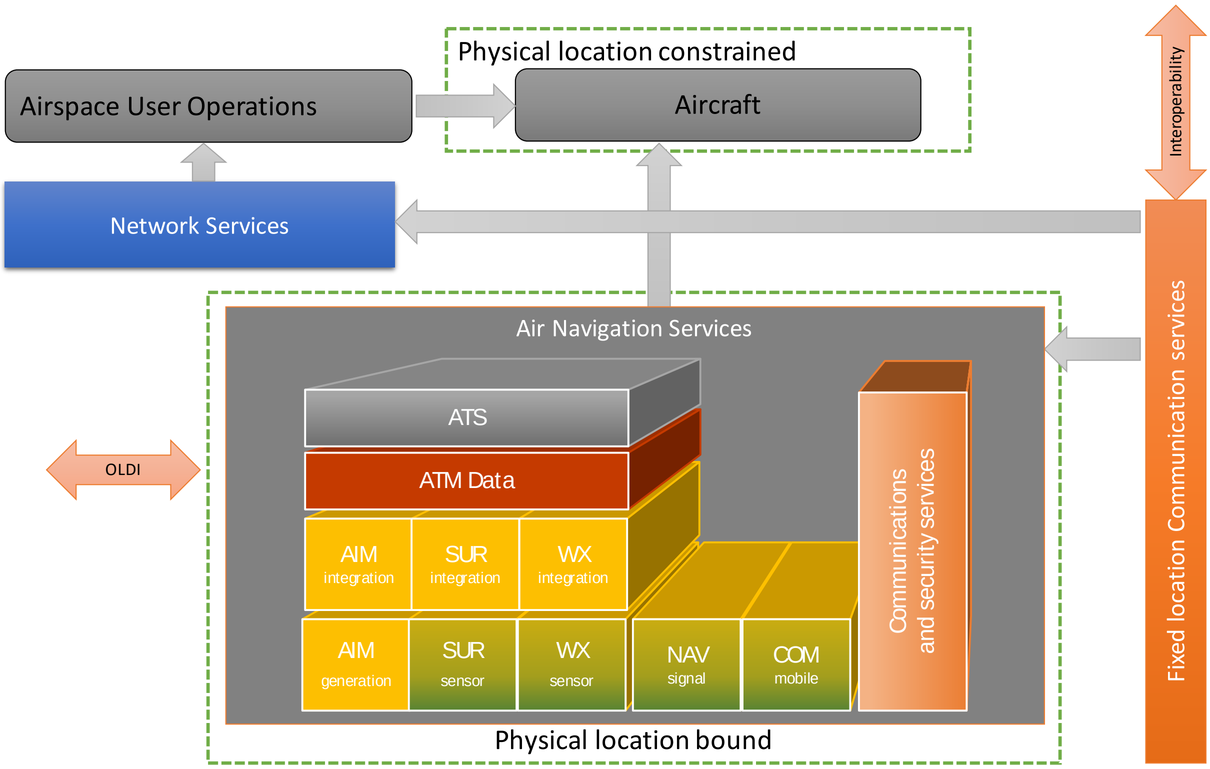


Figure 10. Traditional "monolithic" set-up, with all functions tightly integrated within the same ANSP[27]

The level of automation support available to controllers varies between ACCs (e.g. some controllers use electronic strips while others continue working with paper strips); but overall remains low. To some extent, the deployment of advanced automation tools has been hampered as well by the lack of a robust digital datalink. Higher levels of automation will progressively enable increased controller productivity and hence airspace capacity.

[27] Source: SESARJU, 2018

3.2 Factors limiting overall capacity

3.2.1 Non-optimal organisation of airspace

Airspace is organised in flight/upper flight information regions (FIRs/UIRs) that cover national and, if relevant, High Seas airspace. In each FIR, or across FIRs, one or several air control centre (ACC) and/or upper area control centres (UAC), provide en-route air traffic services. The current areas of responsibility of ACCs/UACs are designed mainly based on national boundaries. There are a number of examples of ACCs/UACs involving cross-border delegations. Each ACC/UAC is sub-divided into designed portions of airspace called sectors which may be grouped together or operated individually depending on level of traffic. Sector design within an ACC/UAC can be very different depending on the complexity of the area and the density of traffic. As such, in complex airspace with high traffic, sectors are highly organised and relatively small. Although these sectors can be grouped in different ways allowing a variety of airspace configurations, there is little additional capacity to be gained by further splitting these sectors as this would create more workload in coordination and potential safety issues taking into account of traffic flows.

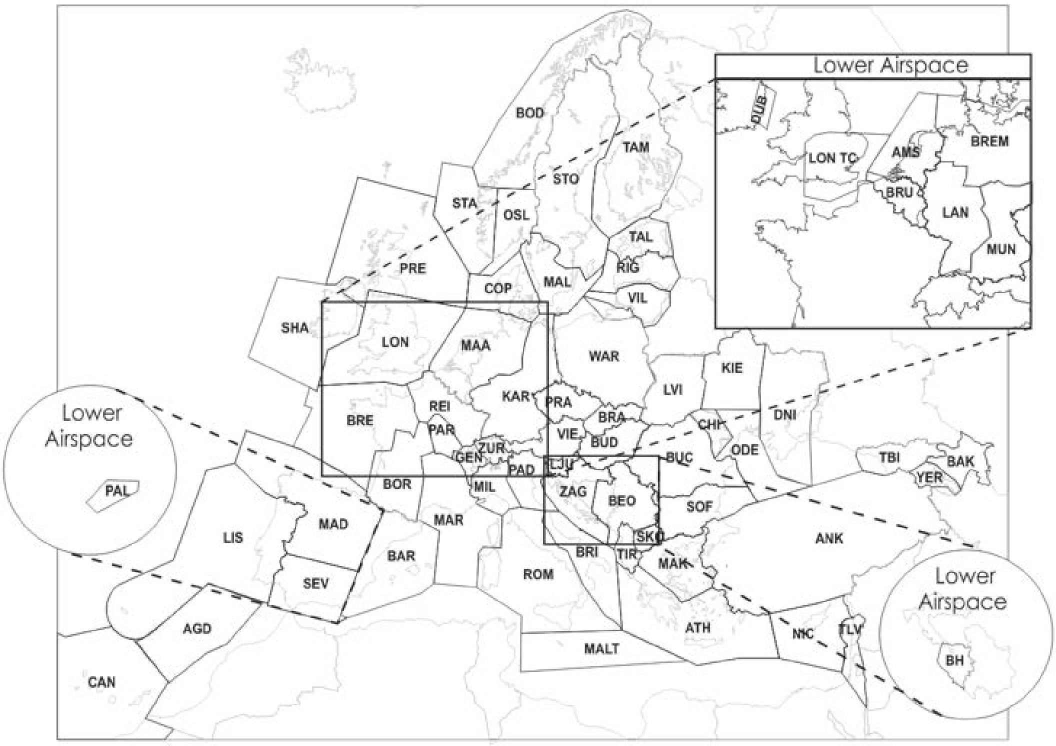


Figure 11. Map of ACCs / UACs[28]

Sector design within an FIR is dependent on the complexity of the area and the flow and density of traffic. Optimisation requires traffic flows to be the main design factor regardless of FIR boundaries.

[28] Source: Eurocontrol/Network Manager, 2018

3.2.2 Limited opportunity to create new sectors

Splitting sectors can reduce the number of flights handled within a sector reducing controller workload on conflict detection and resolution. However, splitting sectors increases the need to coordinate across sector boundaries and increases controller workload for these tasks. Sector splitting may also introduce new inefficiencies, and thus the loss of sector capacity, due to the lack of space to resolve potential conflicts. In particular for small and complex sectors, there is little or no capacity to be gained by further splitting these sectors.

In addition each new sector requires a new radio frequency to operate air-ground communications. The lack of frequencies available in Europe limits the ability to add of new sectors[29].

3.2.3 Limited use of data communications

Instructions issued by a controller to the pilot use voice communications and are limited to standard ICAO phraseology. These limitations are preventing an evolution towards more sophisticated interactions between controllers and pilots that would reduce controller workload, increase capacity, and enable the more optimised flight trajectories from an airspace user perspective. Voice communication tasks represent between 35% and 50% of the executive controller's overall workload. Frequency congestion on sector frequencies is a well-known constraint, such that the current voice intensive process leads to high saturation of radio frequencies and is a constraining factor in determining sector capacity.

Europe is currently investing in datalink for en-route services. The controller-pilot data link communication (CPDLC) services enable routine ATC clearances to be automated. The use of a supplementary communication medium like CPDLC offers the potential to relieve some congestion and reduce workload. A 75% CPDLC equipage rate is estimated to generate an 11% reduction in ATC workload[30].

Data communication is essential to ATM modernisation to enable more sophisticated interactions between air traffic controllers and pilots. While CPDLC has proven to be an important feature, it is yet just one of the many other data communication services and innovations that are needed to improve ATM performance. SESAR has already validated a wide range of new services that are standardised (e.g. ATN Baseline 2) and that have yet to be considered for implementation.

3.2.4 Limited automation support for controllers

In the current systems, the automation support for controllers is limited. The availability of information that may impact of a flight's trajectory is limited. Traffic surveillance, conflict detection and conflict resolutions are all processes that are done in the controller's mind by building up a mental picture of the flights intent.

Some automation support is available to a controller for assessing the detailed intentions of a flight and for assessing the impact of an ATC instruction before issuing it to the pilot; an ATC instruction has to resolve a conflict but shall not create other conflicts while doing so.

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[29] Source: Eurocontrol/ Network Manager Radio Frequency Function

[30] Source: Draft Rule for the Provision and Use of Data Link Services, Economic Appraisal, February 2007

These limitations on automation support imply that significant human effort is still required to manage traffic. Additional automation is a key capacity enabler, because it enables greater capacity within a sector.

3.3 Factors limiting scalability and resilience

3.3.1 Limited predictability

Many factors that influence a flight's trajectory are not known before departure; this limits the predictability of a flight's trajectory, and consequently has a negative impact on ATC capacity.

Before take-off, passengers may arrive late, a tow-truck may be late for pushback or the runway capacity may be reduced due to weather resulting in a queue of aircraft waiting to depart. During a flight, procedures for the hand-over of flights between different ACCs exist but are unknown to the airspace user. These may limit available cruise altitudes or specify entry points for entering the adjacent sector. Potential conflicts between airborne flights are continuously being resolved by controllers through issuing instructions impacting the vertical path, lateral path, and speed. Changes in the availability of airspace may also occur due to military reservations or severe weather.

As all these influencing factors "happen" during the flight, but due to limited connectivity between systems, these factors are unknown to the downstream ACCs resulting in uncertainty in terms of the altitude, route and arrival time of the aircraft at the sectors' entry points. In turn, this uncertainty leads to non-optimum flight profiles and non-optimal conflict resolution in the ATM network, which is pre-tactically optimised without knowing how the flight's trajectory will actually be influenced during the flight.

Driven by the need for safety, sector capacity buffers across the planning and execution phases, are introduced to compensate for the limitations in predictability thus limiting the efficient use of controller resources (see Figure 12). These safety buffers result in reducing the actually available sector capacity.

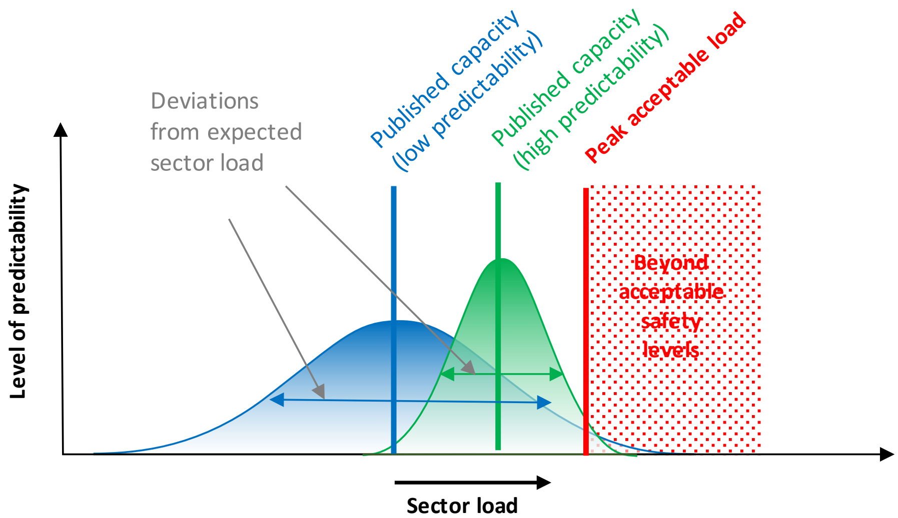


Figure 12. The relationship between published sector capacity and uncertainty in the actual sector load[31]

[31] Source: SESAR Joint Undertaking, 2019

The published sector capacity that can be safely utilised, and used as input for potential traffic regulations, is therefore lower than the peak acceptable load. The level of capacity reduction is proportional to the uncertainty in the flight-trajectory. The higher the predictability (green versus blue), the closer the published sector capacity can be to the peak acceptable load.

3.3.2 Limited information sharing and interoperability

With today's system the possibility to reduce the lack of information sharing described in the previous section is limited. This is because interoperability and data sharing between ACCs are built on simple exchange standards that do not include all the factors affecting the flight's trajectory.

For example

- The aeronautical information, weather information and flight data necessary to provide air navigation services in a particular geographical area are only configured for the system responsible for that area. Bespoke technologies and non-harmonised procedures make it cumbersome to share the same information with other operators.
- Most ANSP systems are relatively monolithic systems with proprietary interfaces that cannot easily interface with systems from other industrial providers apart from a few required interfaces (e.g. on-line data interchange - OLDI).
- The current semi-static aeronautical information regulation and control (AIRAC) cycle does not facilitate dynamic changes in configuration.
- Coordinating on available civil/military airspace at network level is possible. More use of the flexibility provided by the availability of the civil/military airspace is required from the civil users to minimise the loss of airspace for civil purposes.

The current limits on interoperability and data sharing result in limitations on predictability, and therefore the network as a whole operates in sub-optimal manner.

3.3.3 Limited flexibility in the use of ATCO resources across ACCs

In current operations, airspace is organised in sectors, and each controller is responsible for controlling within one sector only, with the most usual setup being one planner and one executive controller taking full responsibility for a sector. Each sector has its own specificities in terms of shape, available routes, exit and entry points to the lower airspace, traffic patterns, etc. For a controller to be able to work in a sector, he must hold not only a generic controller licence, but also be trained and certified to understand and deal with the specificities of the sector. Sector training programmes typically include both classroom and simulator training, as well as on-the-job training with live traffic with an instructor. The instructor for the live on-the-job training sessions must be a controller who holds both the sector endorsement and an on-the-job training rating.

Once a controller is endorsed for a sector, he or she will need to actually control on that sector a minimum number of hours per period (e.g. 30 hours every six months) in order to stay current. The minimum number of actual control hours required for maintaining what is called the unit endorsement for a sector is established by the NSA and depends on the complexity of each sector. When a controller does not fulfil this minimum number of hours, e.g. due to sick leave, maternity leave, or non-operational duty assignments at the ANSP, he needs to be retrained for the sector before he can control on it again.

The larger the number of sectors a controller is endorsed for, the more flexibility for rostering the ANSP will have on any given day (because he can assign the controller to work at any of the sectors he is endorsed for). However, rostering also needs to ensure that controllers maintain the endorsement on all the sectors they can work at; this becomes harder the more sectors each controller is endorsed for. As a consequence, there is a limit to the number of sectors that it is practical to endorse controller for, and European ANSPs providing service to large geographical areas typically have their airspace divided in sector groups, with each controller being able to work only in one of the sector groups, e.g. there are three sector groups in Maastricht Upper Area Control Centre, four sector groups in Karlsruhe Upper Area Control Centre, two en-route sector groups in Madrid Area Control Centre, etc.

The sectors that each controller can be endorsed for poses limitations to the flexibility with which controllers can be assigned to sectors to meet demand, not only across the borders of European en-route control centres, but also within the borders of large European control centres where controllers are not endorsed for all the sectors.

As a result, the availability of ATC Capacity across the network tends to be rigid while traffic demand is variable, both predictably and unpredictably. This results overall in spare capacity and excess load at the same time as illustrated on Figure 13.

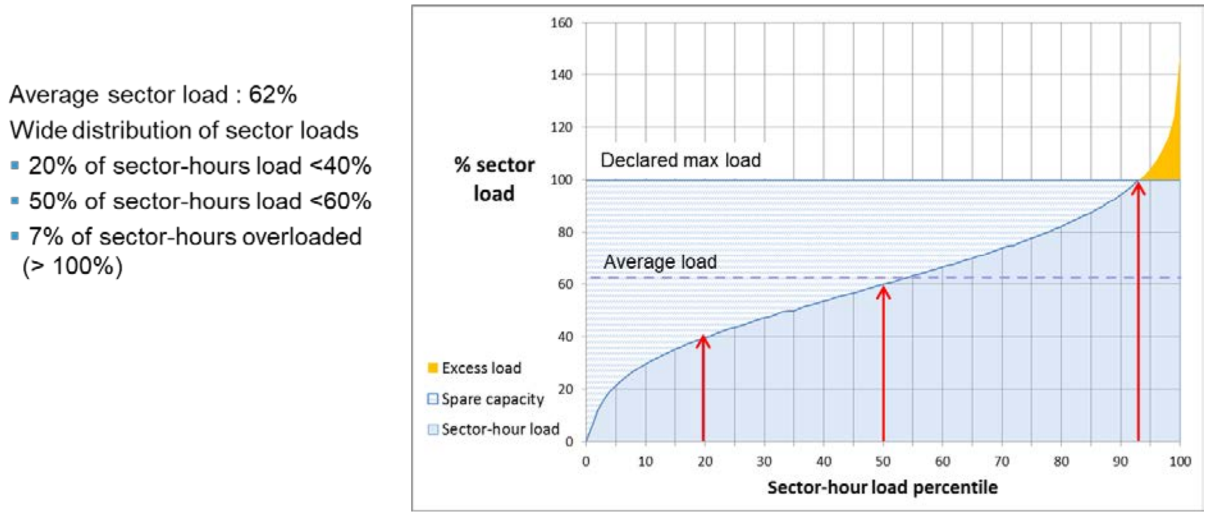


Figure 13. Impact of lack of predictability on capacity

3.3.4 Geographical constraints on technical aspects related to ATS provision

One of the main historical constraints in the set-up of ATM service provision, and a root cause of fragmentation, is the strong coupling between the physical locations, from where the services are provided, in relation to where the service consumer is located. That is each ACC is only able to offer capacity for a fixed and pre-defined volume of airspace.

The main technical constraining factors are:

- The use of low bandwidth, high latency communication technology for ground-ground communications limiting the ability to provide remote services.
- Communication, navigation, and surveillance (CNS) technology using line of sight radio signals, implying that aircraft need to be in the range and visibility volume of the ground equipment. The same is of course also true for space based CNS infrastructure, but the range and visibility volume in that case covers very wide areas.

- Different frequencies for analogue broadcast air-ground radio are used to separate communication responsibilities between air traffic controllers. This requires the coordinated management of a complicated pattern of frequency allocations over the European ATM network as no two antennas using the same frequency should be in concurrent range of any aircraft.

The key technical factors that reduce the geographical dependency for en-route ATM are the significant advances in ground-ground communications and system reliability.

3.4 Conclusion: the current architecture limits capacity

Table 2 summarises the factors identified as limiting overall maximum capacity, as well as capacity scalability and resilience. Most of these are not new and are already known by the industry. They formed the basis upon which the proposed target architecture has been designed.

Factors limiting overall capacity	
Non-optimal organisation of airspace	• The current airspace organisation is not yet fully optimised to network flows and makes limited use of cross-border cooperation.
Limited use of data communications	• The current voice-intensive process leads to high saturation of radio frequencies and can lead to voice communications constraining sector capacity. • More sophisticated interactions between controllers and pilots require datalink communication that can support time and safety critical instructions.
Limited opportunity to create new sectors	• Each sector creation requires a new frequency and there is already limited frequency availability in congested areas. • Some sectors are already very small and cannot be further split unless creating operational issues.
Limited automation support for controllers	• Current technology deployed in most ACCs does not provide an optimal level of automation that would support extra capacity. • Limited automation support means significant human effort is still required to manage traffic. The system as a result also lacks scalability to meet growing demand.
Factors limiting capacity scalability and resilience	
Limited predictability	• High buffers across the planning and execution phases due to limited predictability reduce the actual usage of existing capacity. • Lack of end-to-end trajectory optimisation during both planning and execution phases mean that the capacity potential cannot be achieved at network level.
Limited information sharing and interoperability	• Current limits on interoperability and data sharing lead to sub-optimisation. • Suboptimal view and usage of effective available airspace at network level.
Limited flexibility in the use of ATCO resources across ACCs	• ATCO qualification is limited to a number of sectors or combinations of sectors typically within a specific ACC. This limits their ability to support additional configurations that include sectors from another ACC.
Geographical constraints on air traffic services provision	• The location of all (technical) services that support the provision of air traffic control to an aircraft in today's architecture is tightly coupled to the location of where an aircraft is flying. • This limits the possibility for an ANSP to provide air traffic services beyond its current area of responsibility. • It also limits the possibility to share technical services between multiple ANSPs.

Table 2. Identified limiting factors for capacity in current architecture

4 Proposed target architecture

4.1 Rationale

4.1.1 Objective

In order to meet the challenges described in the previous section, the progressive implementation of a new architecture is proposed in view of enabling seamless European en-route airspace. This new architecture is captured under the notion of Single European Airspace System (SEAS)[32] in which service providers collaborate and operate as if they were one organisation with both airspace and service provision optimised according to traffic patterns.

The proposed target architecture is designed to:

- Deliver an optimised airspace structure, supported by operational harmonisation
- Support increase of ATM capacity and ensure the scalability of the system to handle all en-route airspace air traffic safely and efficiently, even under the highest traffic growth forecast or during traffic growth stagnation or downturn.
- Allow all flights to operate along (or at least as close as possible to) user-preferred routing across the entire ECAC airspace.
- Promote an optimal use of ATM resources, reducing current inefficiencies and ATM costs for airspace users and society.
- Increase the overall resilience of the system to all types of incidents, in terms of safety, efficiency and capacity.
- Facilitate improved civil and military access to European airspace.

To ensure a clear traceability between the problems identified in Section 3, the proposed solutions are presented in two focus areas addressing respectively: Airspace and capacity, and Scalability and resilience (see Figure 14).

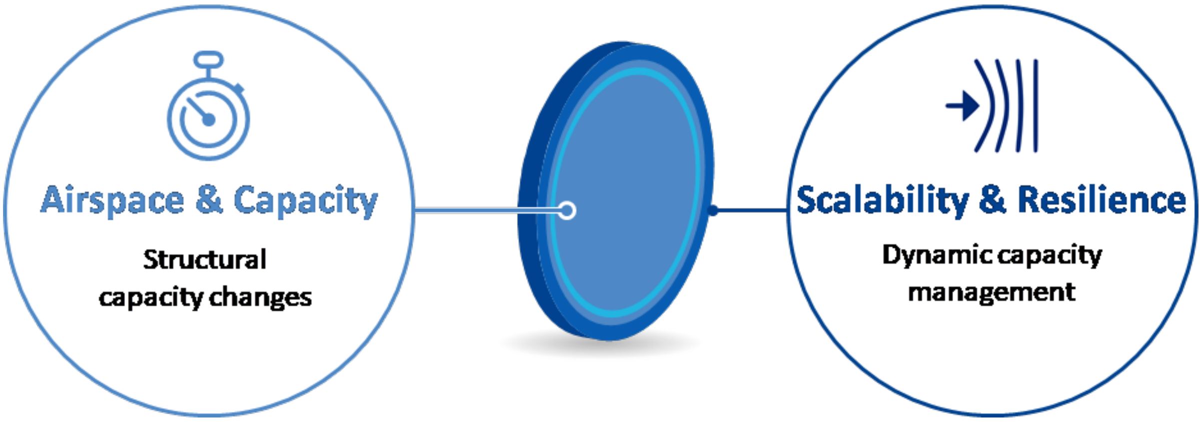


Figure 14. The two sides of the capacity challenge[33]

[32] By analogy of the National Airspace System (NAS) referred to in the USA

[33] Source: SESAR JU, 2018

The contents of each focus area are summarised in Table 3.

Focus area 1: **Airspace and capacity**	• **Optimised airspace organisation** – Solutions that support improved design and use of airspace. • **Operational harmonisation** - Aligning the capacity of control centres and ways of working to best practices through systematic operational improvements. • **Automation and productivity tools** – Increased automation as a progressive enabler of trajectory-based operations (TBO) with short, medium and long-term enhancements to provide increased capacity and predictability.	**Trajectory based operations to address predictability and collaboration -** Deployment of SWIM, 4D trajectory exchange.
Focus area 2: **Scalability and resilience**	• **Virtualisation and ATM data as services** - Transition to virtual centres and a common data layer allowing more flexible provision of ATM services. • **Dynamic management of airspace –** dynamic grouping and de-grouping of sectors and managing the staff resources accordingly • **Flight centric operations where applicable** - Changes the responsibility of ATCO from controlling a piece of airspace to controlling a number of flights along their trajectories. • **Sector-independent ATS operations** - Automation support for controllers to enable provision of ATC without the need for sector specific training and rating. Controller training and licensing to be based on traffic complexity, instead of sector specificities. • **CNS enhancements -** Transition to CNS Infrastructure and Services concept to support performance based CNS and enable new multi-link air-ground communications environment and continued evolution of the Global Navigation Satellite System (GNSS).	

Table 3. Solutions for delivering the proposed target architecture per focus area

It is important to note that both focus areas are part of the transition from today's operational concept to trajectory-based operations (TBO), as envisaged by Phase C of the European ATM Master Plan. The TBO concept is described hereafter.

4.1.2 Trajectory based operations to address predictability and collaboration

The TBO concept is designed to enable airlines to fly their preferred flight trajectories, delivering passengers on time to their destination as cost effectively as possible. Many factors affect aircraft flight trajectory, from take-off to landing. Such factors include delays to take-off time, unexpected weather conditions, air traffic control instructions to avoid airborne conflicts.

TBO takes a holistic look at the trajectory from start to finish. With it, airports, airlines, air traffic service providers (ATSPs) and the Network Manager have access to up-to-date flight, meteorological, airspace and aerodrome information, and a coordinated and synchronised view of each trajectory throughout the operations, from the planning through the flight operations phase.

TBO acts as a glue that binds together the many inter-dependent factors that impact the trajectory. The SESAR R&D programme includes several solutions that will enable trajectory synchronisation as well as investigating how to increase flight trajectory predictability. TBO is built on the foundations of improved synchronisation through better connectivity and sharing of information, and improved multi-stakeholder collaborative decision-making leading to increased predictability for all stakeholders.

Getting off on the right trajectory

Current flight plans have only limited 4D trajectory information and are missing such parameters as the altitude and time between the limited set of filed waypoints, or flight specific performance data. This means that prediction in the air and ground of flight trajectories is misaligned. SESAR's extended flight plan (EFPL) goes beyond the current ICAO minimum flight plan data requirements, to include information relevant to each point of the aircraft's trajectory, for example speed and aircraft mass, as well as other performance data such as planned climb and descent profiles. This allows both air traffic control and the Network Manager to improve their predictions of flight trajectories. This is especially relevant in complex airspace, because it allows better flow management, and also improves the performance of the conflict detection and resolution tools used by controllers.

Syncing air and ground

Modern aircraft feature advanced flight management systems (FMS) which can exchange relevant flight and aircraft data with the airline operations centres (AOC). Air traffic control centres, in turn, have sophisticated flight data processing systems (FDPS) to manage all concerned flight data in their area of responsibility, but there are severe limits in the data communication applications, networks and data links between the FMS and air traffic control ground systems. Introducing air-ground synchronisation of key data covering meteorology (MET), Aeronautical Information Services (AIS) and ATC constraints will enable both airborne and ground trajectory predictors to use the same assumptions. With the extended predicted profile (EPP), the airborne trajectory can be downlinked to the ground systems allowing to ensure consistency between airborne and ground predictions. In turn, using CPDLC, controllers can issue instructions (such as transfers, frequency changes) and clearances (e.g. speed, heading, direct-to, descend-to) using standardised datalink messages.

Syncing ground-ground

Trajectory synchronisation is not just needed between the air and ground. Today each ATSP relies on data contained in their respective systems to predict aircraft trajectory for their portion of airspace, with no synchronised view of the trajectory nor the factors that may constrain it. Ground-ground interoperability solutions will allow controllers to conduct silent coordination between adjacent units. In this way, all concerned air traffic control units hold a consistent view of the flight at all times, which supports seamless cross-border operations, including cross-border free route operations.

4.1.3 Preview of the proposed target architecture

The proposed Single European Airspace System is built on optimised airspace organisation, supported by progressively higher levels of automation and common ATM data services to deliver seamless air traffic services.

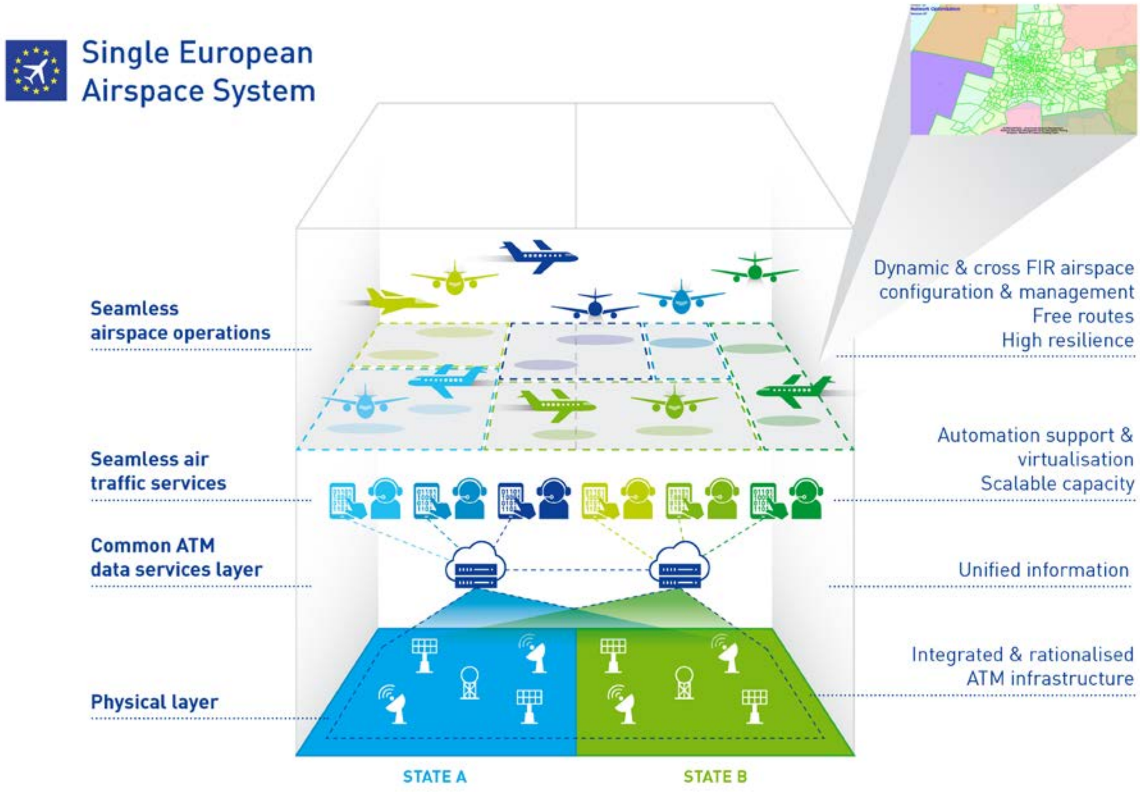


Figure 15 Single European Airspace System[34]

In the proposed target architecture vision, aircraft and IFR RPAS will progressively be integrated across the whole ECAC region and will no longer be constrained by fixed routes. The airspace organisation combined with the operational and technology layer will enable the aircraft to fly in a free route environment allowing them to optimise their flight trajectories irrespective of FIRs or states boundaries.

States will nominally control air traffic within their own territory, however arrangements will be in place such that controllers in an ACC may be allocated to sectors from a different ACC. High capacity sectors operations across all states will be harmonised on shared best practices, highly interoperable across the whole ECAC region. Sectors and sector groups will have been redesigned or reconfigured in maximum support of traffic flows, safely optimising throughput irrespective of national boundaries, and ensuring connectivity between en-route airspace, terminal airspace and their corresponding airports. Sectors that cover airspace of two or more States (cross-FIR) will be common practice. Sectors will be dynamically configured and capacity will be dynamically adapted based on the actual demand of traffic and availability of resources. Airspace will be managed in a flexible and seamless civil/military coordination, minimising the impact of military activities on the network while still fully meeting the needs of the military airspace users.

[34] Source: SESAR JU, 2019

Progressive increase of automation support as well as increased usage of data link for issuing time- and safety critical instructions, will have reduced manual intervention, allowing controllers to handle more aircraft at any time. This will include providing support to the controllers to deal with sector specifics, enabling them to control traffic within a substantially increased number of sectors. Controllers will progressively be trained and certified on a system basis with a decreasing need for training on the airspace and specific sectors. Consequently, cooperative arrangements will have been progressively established across FIRs or across ANSPs or states to bring in additional capacity where and when it is needed for securing additional resilience and scalability to ATM operations.

ACCs will be connected to one common and virtualised ATM data service layer. Each state may still provide through the designed ANSP its own ATM data service, but ATM data services from other providers can be used seamlessly. ATM data services will integrate flight information, weather, surveillance and aeronautical information from multiple states allowing the ATM data service operating in one state to serve as seamless back-up for another state's ATM data service.

The physical layer will be rationalised where possible, without losing coverage of any area. It will be operated independently from the ACCs and serves all ATM data service providers.

Due to flexibility for routing, allocation of controllers, and choice of ATM data service provider, the ATM system as a whole will be more resilient and scalable. System disruptions will have limited impact on airspace users, and capacity adapts more flexibly to the airspace users demand.

4.2 Focus area 1: Airspace and capacity

4.2.1 Optimised airspace organisation

A key element of the proposal is an airspace optimisation process that includes both the extension of free route airspace (FRA) and flexible use of airspace (FUA), as well a progressive re-sectorisation based on dominant traffic flows. The following sections describe these proposals; details of the relevant SESAR Solutions are provided in Annex E.

4.2.1.1 ECAC-wide free route airspace and flexible use of airspace

The objective of FRA, as included in the Pilot Common Project (PCP)[35], is to increase flight efficiency. In itself, it does not contribute to an increase of capacity or resilience of the ATM system. However, FRA is transforming the operational environment in which flights are planned and executed and therefore supports the transformation by the other elements or the proposed architecture.

The creation of a seamless cross-FIR FRA for the whole ECAC region would allow airspace users to fly their preferred route across the entire ECAC airspace (subject to airspace availability, e.g. military airspace reservations, and ATM approval) without intermediate entry and/or exit point inside the ECAC airspace, as is currently the case even between different FRA areas.

The key benefit of ECAC-wide cross-FIR FRA is that it will not only enable improvements in operational performance, in particular flight efficiency but it will also act as a catalyst for optimising ECAC-wide airspace configuration and design, upward harmonisation of productivity across the network, and for the harmonisation of systems. Consequently, ECAC-wide cross-FIR FRA, will require a high degree of interoperability between ATC systems and a progressive increase of automation support to ATCOs to sustain capacity increase of airspace in particular in complex areas.

Current Flexible Use of Airspace (FUA) systems and processes have enabled increased flexibility in civil/military use of airspace. However further improvements could be made to minimise the impact of military activities on the network while still meeting the needs of the military airspace users.

Advanced FUA (A-FUA), as included in the Pilot Common Project (PCP)[36], enables a demand-driven collaborative approach where the civil and military state their needs which are coordinated within the ATM system to provide suitable and balanced solutions. A further refinement of FUA is under development through an enhanced connection between mission trajectory management and fine granular and highly flexible military airspace reservations (dynamic mobile areas) that increase further optimisation of airspace usage in a tight coordination between wing operational centre (WOC) and Network Manager.

4.2.1.2 Optimised cross-FIR sectorisation

An optimal flow-centric redesign of sectors would maximise capacity with minimal changes to controller workload. However, this requires removing some constraints that may be imposed by FIR boundaries. The proposal is to progressively apply the airspace design principles already defined in

[35] Commission implementing regulations (EU) No 716/2014 of 27 June 2014 on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan (the PCP regulation)

[36] Commission implementing regulations (EU) No 716/2014 of 27 June 2014 on the establishment of the Pilot Common Project supporting the implementation of the European Air Traffic Management Master Plan (the PCP regulation)

the Network Functions Implementing Rule[37] to ensure the gradual transformation of the airspace, while building on existing best practices. The airspace design principles are:

- Responding to civil and military airspace users' requirements.
- Responding to operational requirements.
- Irrespective of national/functional airspace bock (FAB)/FIR boundaries.
- Not bound by division between lower/upper airspace.
- Taking into account traffic patterns and forecasts.
- Responding to performance requirements.
- Supporting vertical and horizontal inter-connectivity.
- Enabling ATC sectors to be designed along traffic flows alignments and allowing adaptable sector configurations.
- Facilitating agreements on service provision across national/FAB/FIR boundaries.
- Enabling a coordinated approach military airspace needs across national/FAB/FIR boundaries.

Figure 16 illustrates a potential ECAC-wide airspace design that has been developed as part of this study by the Network Manager using the aforementioned principles. The design was developed in order to allow simulation and analysis of the potential benefits of the overall optimisation process. It is not intended to impose this design as the target solution, but merely to illustrate the approach.

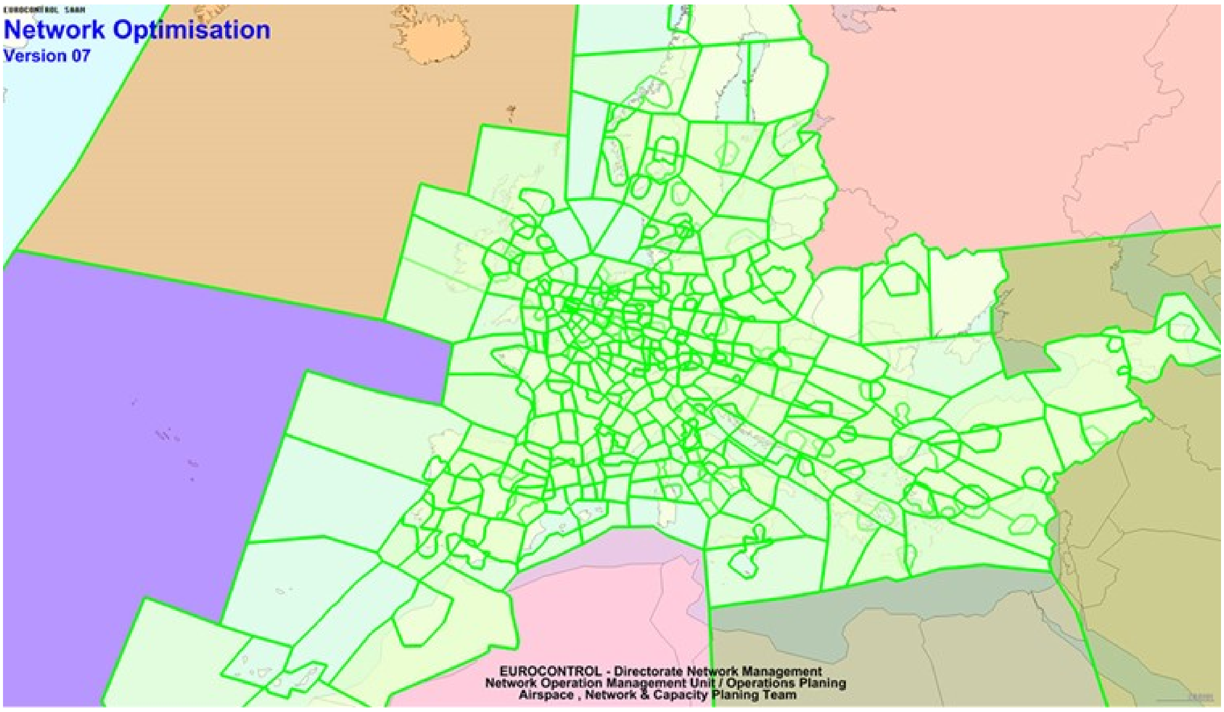


Figure 16. Illustrative optimised design[38]

[37] Commission Regulation (EU) No 677/2011 of 7 July 2011 laying down detailed rules for the implementation of air traffic management (ATM) network functions and amending Regulation (EU) No 691/2010
[38] Source: Eurocontrol/ Network Manager, 2018

The following paragraphs describe the approach that led to this airspace design. A full description of the methodology applied by the Network Manager to define this airspace design improvements is presented in Annex C.

Airspace optimisation design used for the simulations

The airspace optimisation design was developed using the methodology and criteria described in the European Route Network Improvement Plan[39].

The definition of the sector groups was based on an optimised airspace structure, integrating all the airspace components (FRA, route network, supporting sectorisation, multiple route options, etc.). It is also adaptable to evolving future military requirements. The criteria to define Sector Groups are a combination of traffic density, nature of traffic (climbing/descending) and airspace topology (crossing flows, close crossing points).

Particular emphasis was given to the efficient connectivity with terminal airspace. To improve the design and management of terminal routes and ATC sectors serving several airports in close proximity, the fusion of two or more terminal airspace structures have been introduced as referred to as terminal airspace systems (TAS). TASs would probably need to extend across national borders if required by operational requirements.

The total number of sectors resulting from the re-design is slightly less than the number of sectors operated simultaneously today. With these sectors, the traffic increases up to 2025 can be handled at a delay per flight of approximately 0.45-0.5 minutes/flight. Further sectorisation actions are still possible to bring the number of sectors to slightly above those handled today (approximately 700-750 sectors simultaneously opened) and to maintain a delay per flight at approximately 0.5 minutes. The above total number of sectors includes the entire airspace, from Surface (SFC) to FL660, excluding TMAs. The TMA's dimensions and shapes, as well as their contents, have been kept unchanged, but they might require also further evolutions.

4.2.2 Operational harmonisation

In support of the airspace optimisation, a process of operational harmonisation is necessary to reduce the variation in operational performance between ACCs. The objective is to ensure that all ACCs are operating at the performance, in terms of sector throughput, of the current top 10-20% of ACCs. This will also lead to more harmonised operational concept and increased levels of inter-ACC interoperability.

The harmonisation of such best practices would include, inter alia:

- The full alignment of airspace design and airspace management to the principles, requirements and specifications described in the European Route Network Improvement Plan[40];

[39] European Route Network Improvement Plan – Part 1 - European Airspace Design Methodology - General principles and technical specifications for airspace design.

[40] European Route Network Improvement Plan – Part 1 (Technical Specifications for Airspace Design) and Part 3 (ASM Handbook);

- The adaptation of ATC and ATFM operations practices, procedures and manuals;
- The adaptation of ATCO recruitment, training, planning and rostering;
- The adaptation of system support, ATC and ATFM tools and data utilisation to ensure fully interoperable systems and data exchange between ATC units, airports, airspace users and with the Network Manager;
- The implementation of harmonised practices and procedures for post-operations monitoring, lessons learned and continuous improvement.

The Network Manager's simulations (see Annex C) suggest that improvements in these areas coupled with the implementation of an optimised airspace organisation has the potential to increase significantly the European airspace capacity as further detailed in chapter 7 and in Annex C.

The precise nature of the actions will depend on the local specificities of each ANSP and ACC, and may include minor or quite significant harmonisation actions, as well as the harmonised deployment in the short term of specific SESAR solutions – including those from the PCP.

4.2.3 Automation and productivity tools

Automation is central to the achievement of TBO and to the broader vision of the ATM Master Plan since it is seen as a key enabler for the overall increased performance of the ATM system.

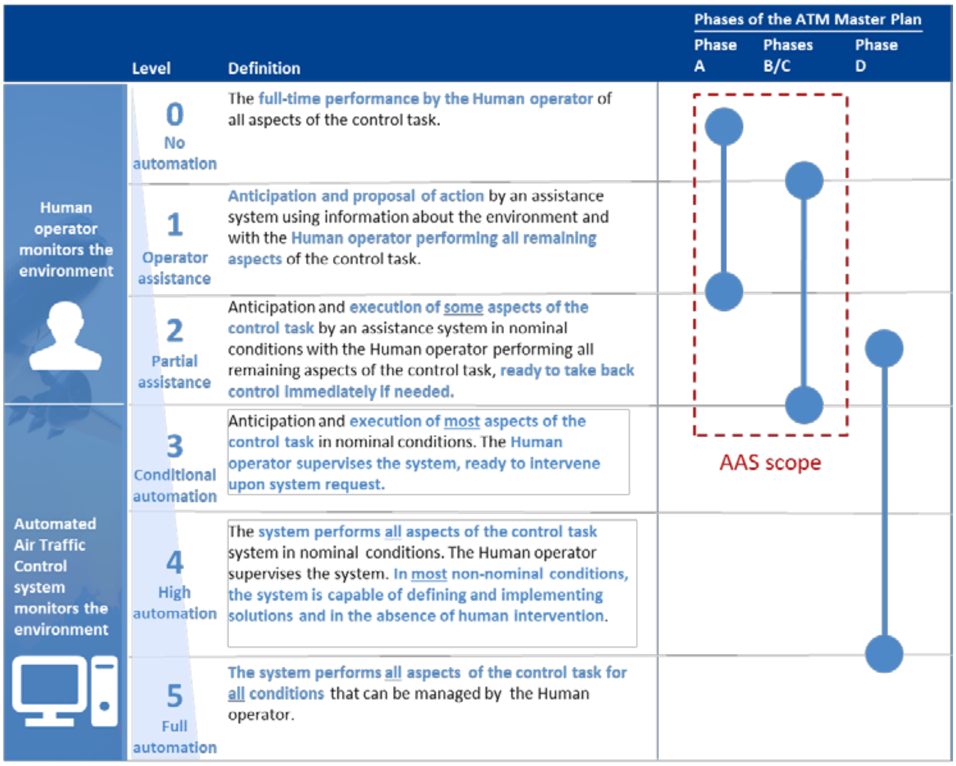


Figure 17. SESAR's automation model under development for the Master Plan Edition 2019[41]

[41] Source: SESAR JU, 2018

Figure 17 illustrates an ATM automation model under development in the context of the Master Plan update campaign that mirrors the five-level model from the Society of Automotive Engineers (SAE) (ranging from level 0 "no automation" to level 5: "full automation").

The general evolution of ATCO controller support starts with solutions that improve the information provision to the controller regarding the factors influencing a flight's trajectory. This is followed by solutions that provide support to decision making in nominal conditions helping the controller in finding conflict resolution solutions.

From one level of automation to the next, the role and responsibilities of the controller therefore change progressively. As depicted in Figure 17, there will be an evolution towards a partnership between human and machine, where each has their defined roles and trusts the other to perform their tasks accordingly (with appropriate the means for safety assurance and relevant certification). Alongside the evolution of automation levels, further research work will be required in the future to allow a transition in the controller's role in order to maximise the contribution of automation to improved capacity and resilience.

Figure 17 also illustrates the level of automation anticipated for each phase of the European ATM Master Plan. The final target within the scope of this study, equivalent to phase C of the Master Plan, involves technical solutions that can independently execute a subset of controller tasks in nominal conditions under the supervision of the controller (level 2 in Figure 17). Therefore, the solutions considered within this study do not require a dramatic change to the current human responsibilities.

Although not considered in the scope of this study, it is important to note that higher levels of automation may be needed in order to optimise capacity and increase the resilience of the system in light of the expected future growth and complexity in traffic. Phase D of the Master Plan may include high automation solutions (level 4).

Numerous SESAR solution support controller productivity gains through automation. Some key examples are outlined in Table 4.

Medium-term conflict detection (MTCD) and conformation monitoring tools	Use of tools to increase controller productivity and safety including an improved human machine interface (HMI) and revolutionary use of tactical trajectory for conflict detection and resolution (CD&R) and conformance monitoring (MONA).
Advanced separation management	Use of air-ground synchronisation (EPP) and CPDLC for advanced separation management, more precise ground trajectory and improved algorithms (e.g. "what-if" and "what-else" functions).
High productivity controller team organisation	Extension of multi sector planning (MSP) to support collaborative control with coordination-free transfer between executive controllers supported by the same planner.
Collaborative advanced planning	Coordination of re-routing between multiple ACCs and airspace users including synchronisation with the Network Manager enabling increased predictability.

Table 4: Example SESAR Solutions supporting increased productivity

Further details of these and other pertinent solutions, are provided in Annex E. These solutions are part of the transition to TBO; full implementation of TBO also requires elements of Focus Area 2 as discussed in the next section to ensure full data sharing.

4.3 Focus area 2: Scalability and Resilience

Focus area 2 looks at enabling a more dynamic management of capacity so that the ATM system is more flexible, scalable and resilient. The essence of the proposal is the introduction of a new service-oriented architecture that enables the transition to TBO.

4.3.1 A progressive introduction of a new service-oriented architecture

4.3.1.1 The proposed target architecture

The proposed high-level logical architecture is illustrated in Figure 18. The aim is not to prescribe specific implementation choices in terms of service provision, but merely to provide a flexible architecture that allows stakeholders to choose their desired implementation options. The logical architecture is the starting point for identifying a virtual infrastructure that enables vertical and geographical decoupling of services; this will enable the re-integration of services in a manner that increases flexibility, scalability and resilience. The rationale and technical benefits of the architecture are discussed in Annex D.

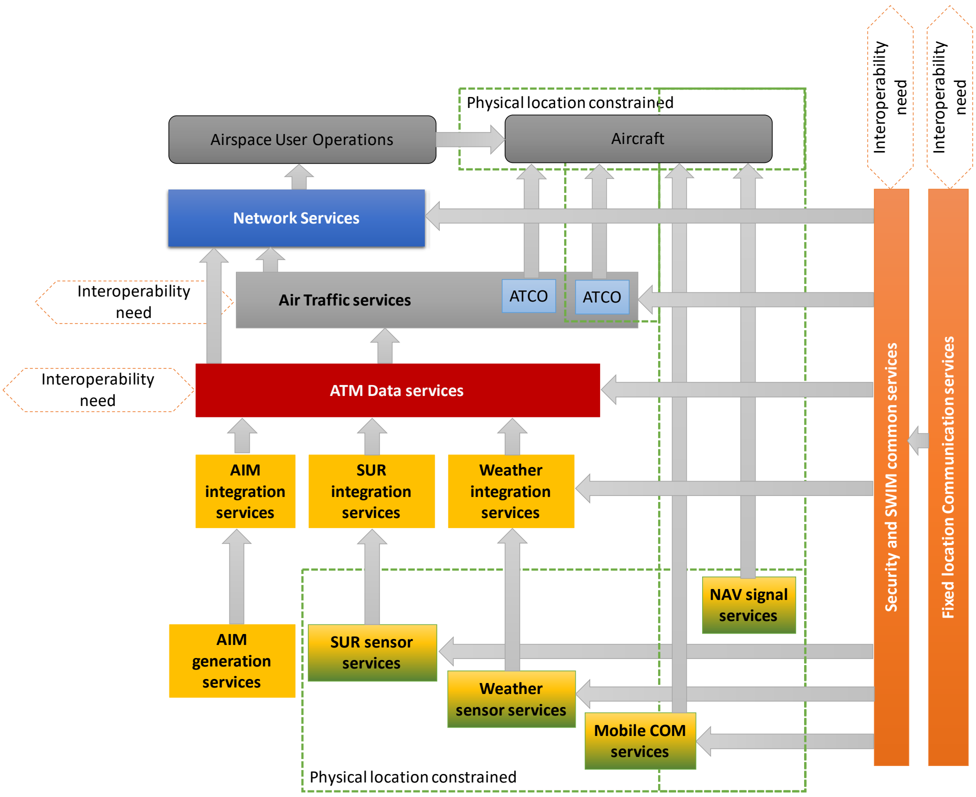


Figure 18. Proposed service-oriented architecture depicting service (not information exchange) flows[42]

[42] Source: SESAR JU, 2018

When aiming to decouple services vertically and geographically, it is important to note that some services within the architecture have a fixed relationship with their geographical location. This is the case for the CNS physical equipment like antennas, radars, beacons that send and/or receive radio signals, as well as meteorological sensors. Aircraft also have a given physical location relative to the CNS systems at any moment in time. All the other services in this logical architecture can be defined such that their geographical area of coverage/responsibility is either irrelevant, dynamically configurable or fixed. They can be offered in a virtual manner as outlined below.

4.3.1.2 Virtualisation and ATM data as services

A virtual centre is composed by one or more air traffic service units (ATSU) using ATM data services provided remotely. The concept enables the geographical and ultimately organisational decoupling of ATM data service providers from ATSUs. An ATSU may use ATM data services from multiple providers, just as a data provider may serve multiple ATSUs and even multiple ATSPs.

Table 5 defines the services required by the virtual centre concept. These services can be provided independently from one another by different service providers.

Air traffic services (ATS)	ATS is the core service that maintains separation between aircraft, expedites and maintains an orderly flow of air traffic. Clearances are issued by air traffic control units to pilots to provide separation. The provision of ATS by controllers relies on the underlying ATM data services.
ATM data services	The ATM data services provide the data required to provide ATS. It includes flight data processing related functions like flight correlation, trajectory prediction, conflict detection and conflict resolution, and arrival management planning. These services rely on underlying integration services for weather, surveillance and aeronautical information. They also include the coordination and synchronisation of ATM data in function of all trajectory interactions by the providers of ATS.
Integration services	The integration services for aeronautical information management (AIM), surveillance (SUR) and weather combine the geographically constrained scope of the underlying provision services in a service with a broader geographical coverage. By building on performance-based service requirements and standardised interfaces, these services can be built up from different underlying geo-graphically-fixed services with different qualities from different providers (e.g. satellite ADS-B or radar-based surveillance services).
Geographically-fixed services	These are services that have a fixed relationship with a geographical location. They include the provision of navigation signals, weather and surveillance sensors and the provision of air-ground antennae.

Table 5. Services for composing virtual centres

In addition, to the virtual centre services, the architecture also requires services provided at Network level:

Network services	Including air traffic flow and capacity management (ATFCM), existing network functions and network crisis management.
Transversal services	Including system-wide information management (SWIM), ground-ground communications and security services.

Figure 19 presents the current classification of the ANS within the SES Regulations[43]. Currently ATM data services form an integral part of ATS; the study proposes that a new form of ANS is defined specifically for ATM data services (the green box in Figure 19) so that the services may be provided independently of ATSPs in the same way that CNS, AIS and MET services are today. The regulatory assessment of this issue is presented in Annex F.

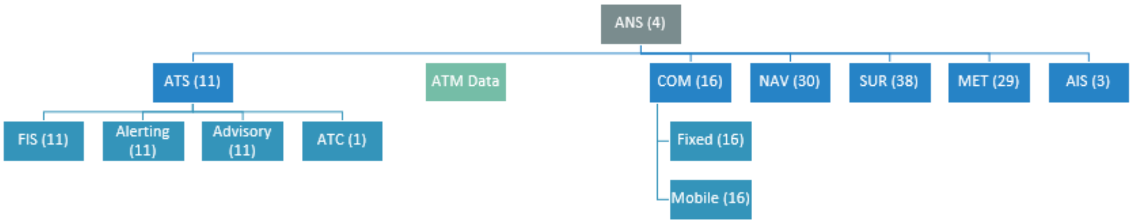


Figure 19: proposed extension of the SES ANS taxonomy for ATM Data services

Further details of the proposed target architecture are provided in Annex D with details of each component. The relevant SESAR Solutions are described in Annex E.

4.3.2 Enabling higher capabilities and performance

The proposed target architecture has the potential to enable new types of services that are more scalable to demand. The key to success is to allow both existing service providers and new entrants (including groups of existing providers) to operate such services.

By enabling this type of new service, the new architecture will lead to an increase in reliability in the en-route airspace. The ATM system will be more resilient to disruptions and changing demand, resulting in a stable ATM service for airspace users anywhere in en-route European airspace. The following sections provide details of potential enhancements based on existing SESAR Solutions.

4.3.2.1 Dynamic management of airspace

The dynamic management of airspace is a wide concept designed to improve the use of airspace capacity for both civil and military users by increasing the granularity and the flexibility in the airspace configuration and management within and across ANSPs' areas of responsibilities.

This includes the integration of technology and procedures to allow sectorisation to be dynamically modified based on demand.

A key benefit is the ability to adapt capacity to the traffic load by enabling sectors to be controlled by the most appropriate ACC.

Figure 20 illustrates the traditional arrangement (sectors statically controlled from one ACC) and two potential configurations under the dynamic management of airspace configuration concept (D_x and D_y configurations). Between D_x and D_y configurations, the management of sectors S04, S07 and S08 is

[43] The number in brackets refers to the number of the definition from Article 2 of the framework Regulation.

shared between ACC2 and ACC1. The concept enables a wider set of options for sector openings and hence offers greater opportunities to align traffic and staff availability.

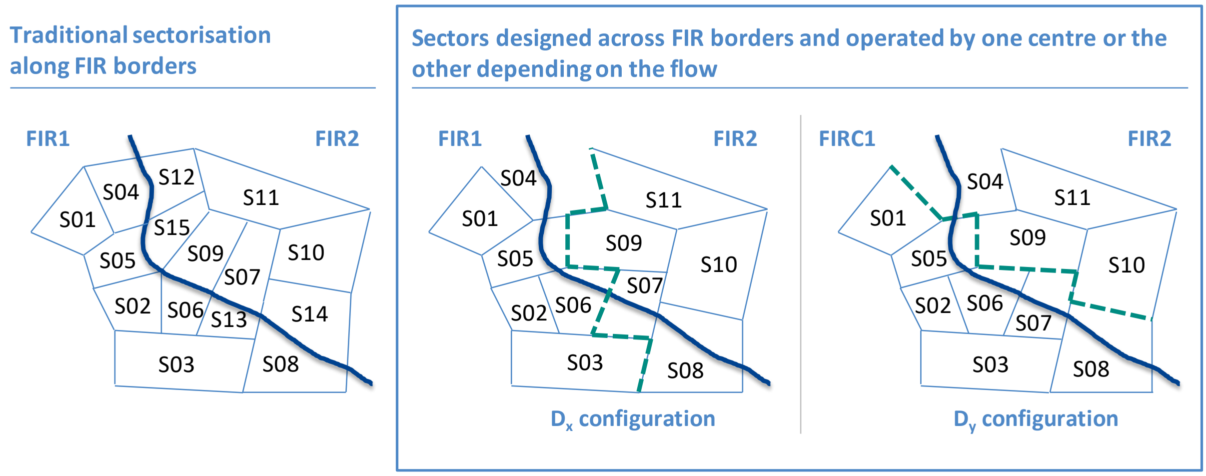


Figure 20: Dynamic management of airspace[44]

The concept enables the detection of potential sector overloads and propose alternative airspace configurations that prevent the overload.

The relevant SESAR solutions are described in Annex E.

4.3.2.2 Flight-centric operations

The flight-centric concept changes the responsibility of the controller from controlling a piece of airspace to controlling a number of flights along their respective trajectories (see Figure 21). Several executive controllers share the responsibility of the flight-centric portion of airspace.

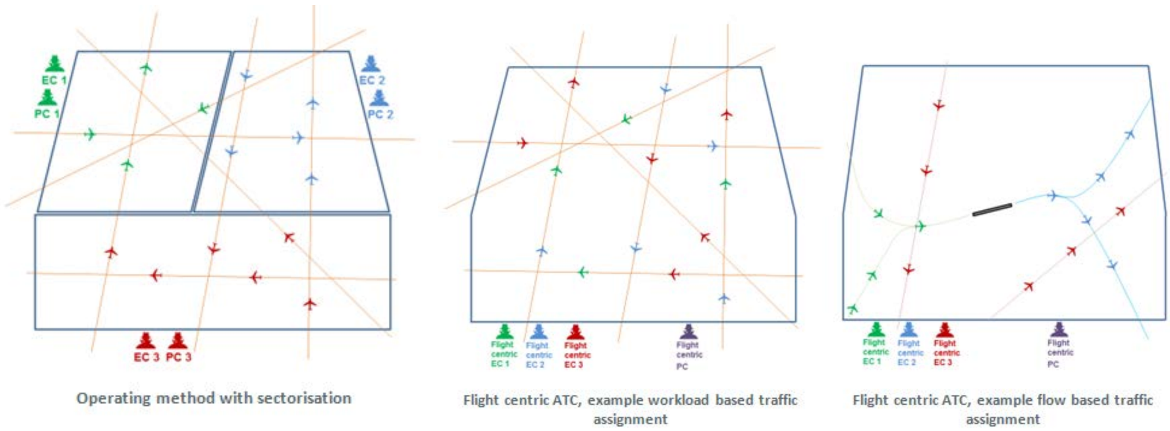


Figure 21: Illustration of the flight centric concept[45]

[44] Source: SESAR JU, 2018
[45] Source: SESAR JU, 2018

With this concept, incoming flights are allocated according to a pre-established logic (such as flight interaction, traffic flows or complexity) to the least busy controller, thereby achieving a more balanced distribution of workload and improved scalability.

If proven feasible, together with virtualisation, flight-centric operations would allow for flight-centric distributed controller teams, providing greater flexibility for ANSPs to pool resources.

The relevant SESAR solutions are described in Annex E.

4.3.2.3 Sector-independent controller training and licensing

SESAR is researching how to overcome limitations of controller training and licensing in complex airspace by expanding the number of sectors that a controller can be validated for by providing automation support so that controllers' in-depth knowledge of the local area can be progressively complemented by the system. For instance, research is investigating how to validate controllers to work with a specific system and traffic complexity, regardless of the geographical area where the service is delivered.

It results in automation support on sector-specific aspects in support of controllers to provide ATC with a more limited need for sector-specific training and rating. Controller training and licensing can then be based on system functionalities and traffic complexity instead of airspace/sector specificities.

The relevant SESAR Solutions are described in Annex E.

4.3.2.4 CNS enhancements

The decoupling of integration services and underlying CNS infrastructure services, allows for a performance based approach to CNS as defined in European ATM Master Plan through the CNS infrastructure and services concept.

CNS infrastructure and services are based on contractual relationships between customer and provider for clearly defined and harmonised services with agreed quality of service levels[46]. An ANSP could, for example, contract a service based on operational needs; the service provider could then combine the available CNS technologies and provide the necessary service that meet the requirements.

The performance-based service delivery is then handled at the level of the integration services, allowing technology specific implementations to develop independently. Multiple services can be simultaneously provided, based on different technologies with different quality of service characteristics, in that way can be seamlessly integrated without the end-user being concerned about the technical implementation.

A datalink with high capacity and fast and reliable response times is required to enable sophisticated interactions between controllers and pilots for time- and safety-critical separation purposes.

[46] For example, the ICAO Required Communications Performance (RCP) levels [ref RCP Manual or ICAO GOLD].

The main elements of CNS Services and Infrastructure are illustrated in Figure 22; including the need for a strong internet protocol (IP) backbone to support connectivity. The relevant SESAR Solutions are described in Annex E.

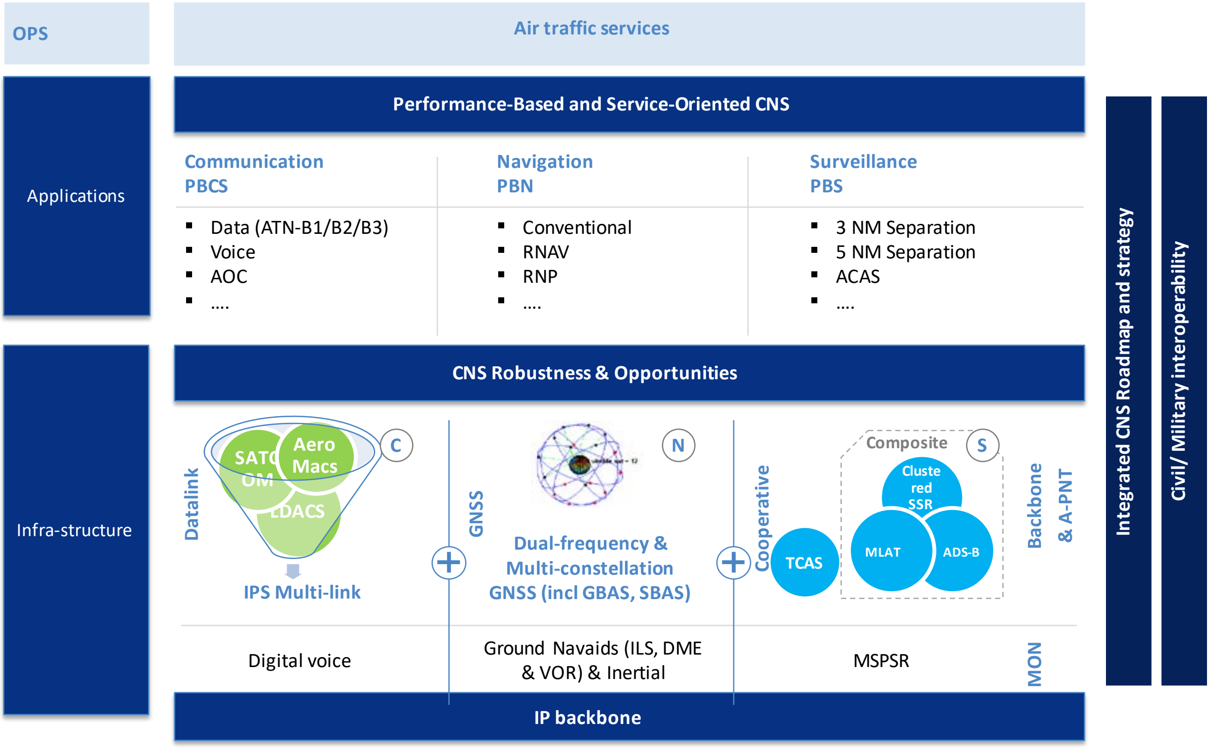


Figure 22: Future CNS Environment[47]

[47] Source: SESAR JU, 2018

5 Conditions for success

The technical and operational improvements required to implement the target architecture represent an evolution of ATM towards a more digital era. They require all stakeholders to adopt new standards, procedures and ways of working; they require investments in new technologies and the development of new services, including availability of cross-FIR ATM data services to enable the virtual de-fragmentation of European Skies, as well as adaptations to the current ATM service delivery model where necessary. These are as well flexible solutions that will enable ANSPs to make implementation choices on how new services are provided.

The right conditions need to exist to catalyse an evolution of the service provision landscape in support of this transition. The current framework will need to consider the integration of potential new service providers aside the existing while ensuring they are both treated in a consistent and equitable manner.

This section therefore explores the introduction of a new capacity-on-demand service, and the creation of dedicated ATM data service providers (ADSPs) as well as targeted support to early movers in implementing high-impact operational improvements or the shift to new service delivery models

5.1 Capacity-on-demand service

Resilience of the ATM system is its ability to adjust to expected and unexpected disturbances (staffing problems, weather disturbances, system failures, cyber-attacks, temporary surge in needed capacity) in order to sustain required operations and secure sufficient capacity. Whenever there is a local disruption that temporarily reduces capacity below demand, there are generally three options:

- Flights are delayed until capacity becomes available.
- Flights are re-routed through airspace with spare capacity.
- Flights are cancelled.

The need for more resilient ATM operations will increase with higher traffic demand, placing pressure on the system to operate even closer to its capacity limits. Not only will more flights and more passengers be impacted if part of the system is forced to operate at reduced capacity, it will also take more time to recover to normal operations.

The low resilience of the current system is due in part to the fact that it relies on the provision of local ATM services for a defined geographical area. When disturbances occur, as illustrated on Figure 23, the system cannot use remote services to mitigate the impact of a disturbance, while recovering and resuming normal operations, unless traffic can be re-routed via providers with spare capacity.

This is where the capacity-on-demand service comes in. It aims to ensure the continuity of air traffic service provision despite disruptions by enabling a temporary delegation of the provision of air traffic services to an alternate provider with spare capacity.

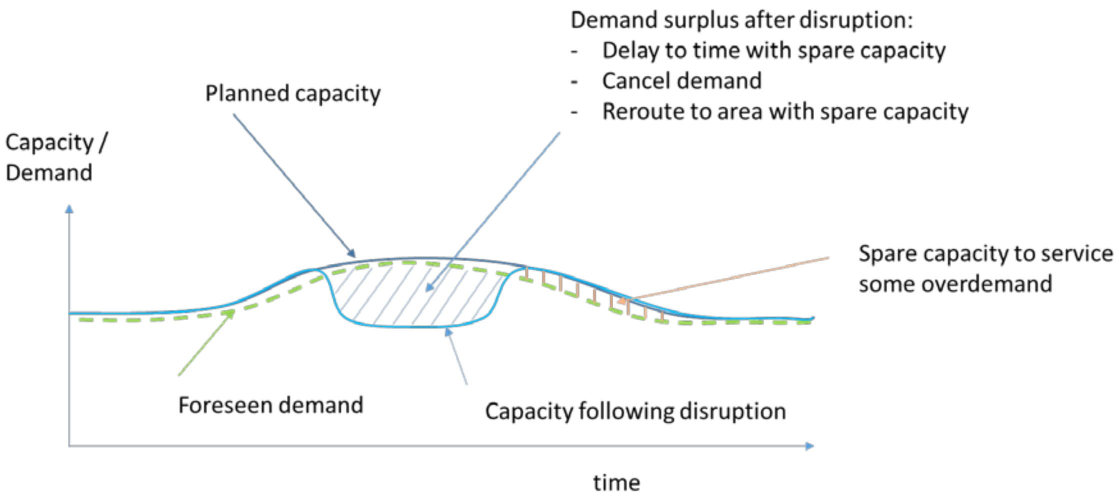


Figure 23: Options for handling reduced capacity due to disruptions[48]

The pre-requisites for delegation to an alternate provider include:

- Availability of common ATM data services at the ACC taking on ATS provision, and the ACC requesting support.
- Automation support on sector-specific aspects in support of controllers to provide ATC without the need for sector-specific training and rating.
- Sector independent controller training and licensing, such that controllers at this ACC are qualified to handle traffic for the appropriate sectors;

Rather than mandating shared management of capacity or forcing specific solutions, the objective is to promote horizontal and voluntary agreements between ANSPs to allow industry members to develop their own model for resilient ATS (see Figure 24) while maintaining a network-centric approach.

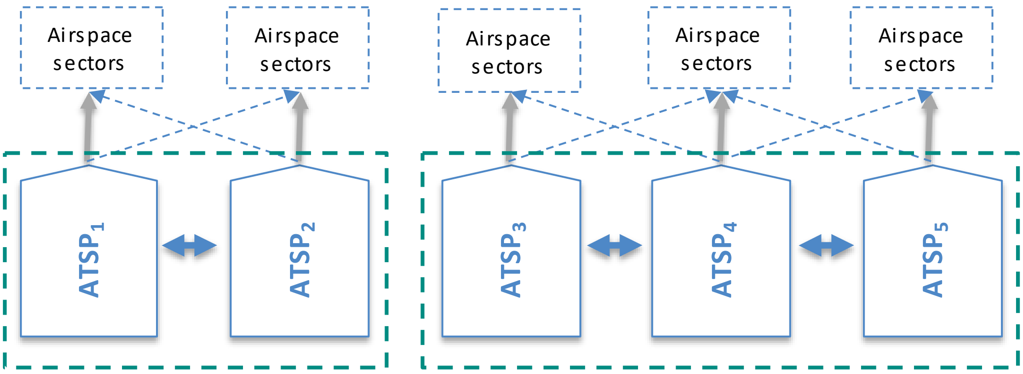


Figure 24. Example of capacity-on-demand service delivery model[49]

[48] Source: SESAR JU, 2018

[49] Source: SESAR JU, 2018

In addition to considering the technical and operational requirements, it is important to establish a regime for oversight and certification consistent with the liability regimes for the provision of ATS. An assessment of the regulatory framework is presented in Annex F.

The capacity-on-demand service goes beyond the current static arrangements for cross-border delegation of ATS and its operational set-up could be more complex from a regulatory perspective. As such, it may be better served by a joint comprehensive designation of all States involved in a specific capacity-on-demand service rather than bilateral arrangements between States.

5.2 ATM data service provision

Currently, air traffic services are almost-everywhere provided by vertically integrated national ATS providers (ATSP) who are each responsible for producing part of the data required for ATS, processing and combining this data to make it available to their controllers and using that data to provide ATS for airspace users. Most of that data is currently not fully shared between ATS providers.

Creating a resilient ATM system will require an evolution of this model; the collaborative management of the airspace, through remote provision of air traffic services, will only be possible if all needed ATM data is available all ACCs. This requires a transition towards common ATM data service provision (see for more detail Annex D.4) in support of several ATS providers simultaneously. Common ATM data services mainly require computational resources, are less dependent on human actors, and therefore are easily scalable.

As illustrated in Figure 25, this could be achieved by supporting the progressive shift to a new service delivery model for the various services identified in 4.3.1.1. While all these services are currently delivered by vertically fully integrated ANSPs, the service model will allow for providers that are more specialised in one or more of these services, while possibly covering geographical areas that go beyond individual FIR boundaries. In this model:

- ATSPs that wish to remain in the current vertically integrated model could continue to do so;
- However, ATSPs may choose to shift to a new model in which they focus on their core capability of ATS delivery and acquire their ATM data services from one or more separate providers (ADSPs), who in turn may depend on separate providers of the underlying ancillary services;
- The ATM data services will need to be interoperable between all providers based on European or ICAO standards.

The maximum scope of service delivery by ADSPs covers the ATM data services (such as flight data processing) needed to realise the virtual de-fragmentation of European skies and includes the provision of AIS, MET and CNS services.

A particular approach that may be preferred by some stakeholders would be the creation of alliances among industry players and/or alternatively create specialised ADSPs and let each ATSP decide on the delivery model best suited to their specificities.

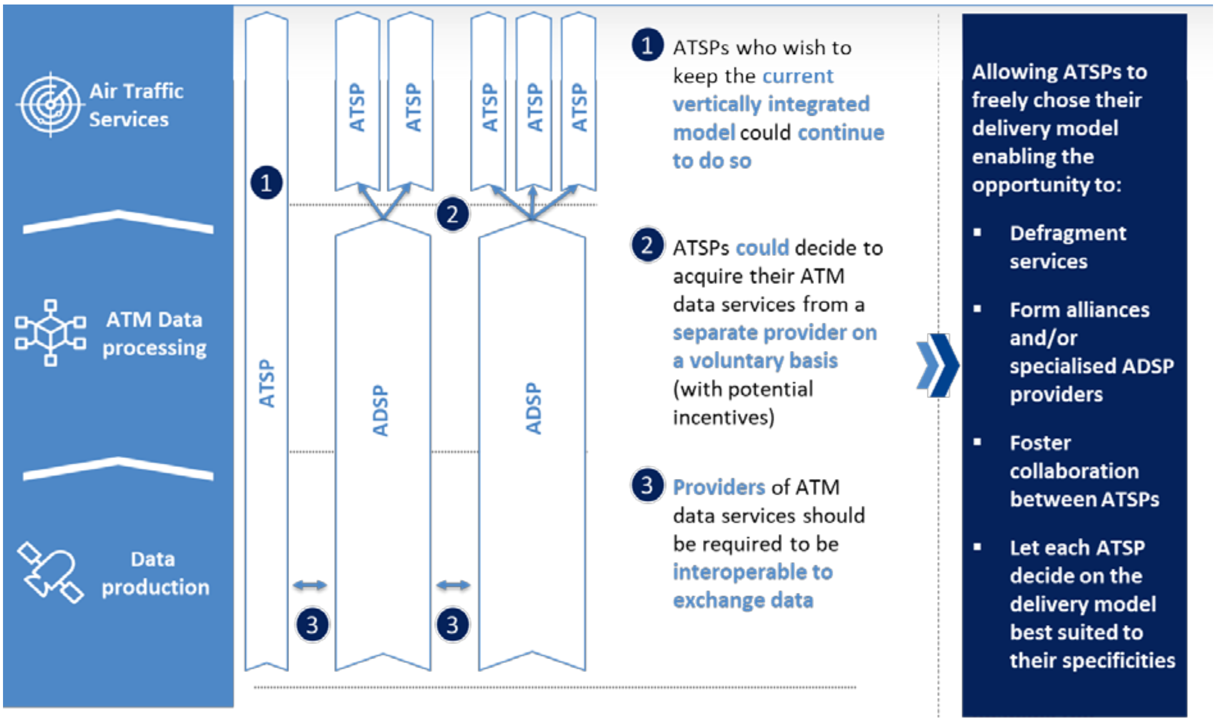


Figure 25. Alternative options for the air traffic service provision model[50]

In this new set-up, and as illustrated on Figure 26, several models could co-exist with the apparition of new delivery models for air traffic service providers:

- **Alliance service delivery model**: certain ATSPs could form alliances by creating a dedicated jointly-owned entity responsible for producing and providing the needed air traffic data for their airspace (e.g. COOPANS/iTEC like model);
- **Independent/integrated service delivery model**: certain ATSPs could transfer all their data infrastructure, systems and operations to an independent entity from which they would “acquire” their air traffic management data services; integration services; and geographically fixed services:
- **Specialised service delivery model**: specialised providers that focus on certain parts of the data service value chain could be created through competitive entry or partial transfer of existing activities by ANSPs.

[50] Source: SJU, 2018

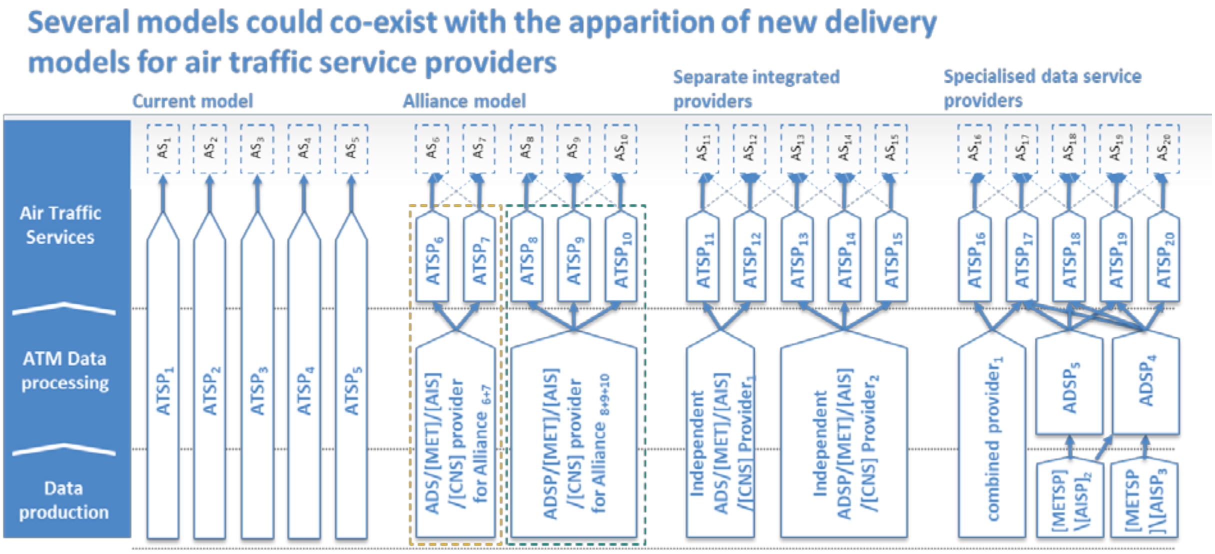


Figure 26. Example of possible air traffic service delivery models[51]

The shift to the new service delivery models could also enable further rationalisation of the underlying infrastructure since the focus will move from investment in a local infrastructure to provision of services complying with performance requirements.

The nature of the services, and in particular their safety criticality, is important in considering the regulatory and certification requirements to be placed on the service providers.

5.3 Targeted incentives for early movers

As will be discussed in the next section, the transition to the proposed target architecture will require significant changes from the ATM community as a whole. While over the foreseen transition period many stakeholders will make changes, a progressive implementation is possible, in particular for the introduction of ADSPs. What is more important is to start moving in the right direction with some stakeholders, expecting that others will eventually follow.

Specific incentives should therefore be offered for those stakeholders that implement recommended operational improvements or that shift towards innovative delivery models with a focus on early movers in order to initiate the transition.

This section presents an illustrative, non-exhaustive, list of such potential incentives.

For airspace users

- Incentives could be provided for airspace users to invest in SESAR-related technologies by lowering en-route charges for those that have equipped their aircraft through innovative ways to implement the existing scheme of modulation of charges, e.g. using EU funding to offer lower charges to equipped aircraft or implementing a “pay per service used” scheme;

[51] Source: SJU, 2018

- Additionally, or alternatively, differential services could be accorded to airspace users that are equipped with SESAR technologies during a pre-determined transition phase (for example through the concept of “best equipped, best served”).

For service providers

- Promote SESAR related investments (with associated oversight measures) and service delivery during performance scheme implementation to support the transition;
- Allow a profit margin to be made for one-to-one agreement of provision of remote ATS capacity (resilient services);
- Reward the achievement of specific key performance indicators (KPIs) (e.g. cost-sharing for operational performance programme or certain investment subject to reaching certain operational or performance targets);
- Allow faster cost depreciation and decommissioning of legacy assets for installing new systems and services;
- Provide European guarantees (equity or debt) for the first stakeholders to enter the market or shift to a new delivery model (e.g. first ANSPs creating a joint ADSP);
- Introduce direct financial support mechanisms (e.g., conditioned grants, faster depreciation of legacy assets) to stimulate the launch of ADSPs meeting certain desired conditions (e.g., transfer of CNS infrastructure to a separate entity, ADSP covering more than one State).

A regulatory assessment of these measures is presented in Annex F. This assessment concludes that whilst the existing regulatory framework already contains measures to incentivise early adopters a more detailed review of incentivisation policies should be undertaken to ensure they can be used together to support early movers through the transition to the proposed target architecture.

6 Transition strategy

A successful transition will only be possible through collaboration and commitment from all ATM stakeholders (not only ANSPs). This section is not an attempt to provide a full transition plan (including detailed actions for each stakeholder) but rather to provide an overall transition strategy together with proposed high-level milestones.

The current regulatory and governance frameworks support the transition in most cases, although refinement might be needed to fully support the proposed changes.

The key enabler for achieving the transition to a service-oriented architecture is the implementation of common attributes on how to manage airspace in common and a common data layer (as outlined previously in Sections 4 and 5). Once established, the architecture will allow different parts of the system to develop at different speeds depending on local needs whilst maintaining an overall coherence and network level.

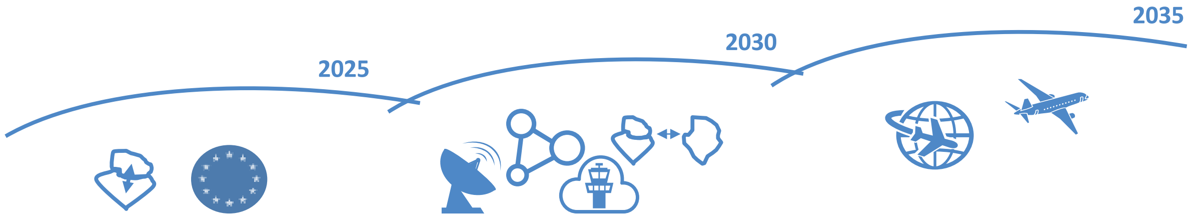
It is also important to note that whilst the focus of this study is the en-route service, similar considerations are required for terminal services and integrating the airports – the capacity challenge is just as equally urgent in terms of runway capacity[52].

6.1 The overall transition strategy

The study does not provide a full transition plan (including detailed actions for each stakeholders) but rather an overall transition strategy together with proposed high-level milestones. The key enabler for achieving the transition to the proposed target architecture is the implementation of common attributes on how to manage airspace in common and a common data layer. Once established, the architecture will allow different parts of the system to develop at different speeds depending on local needs whilst maintaining an overall coherence and network level.

Figure 27 illustrates the main elements of each five-year period during the transition. Each element is described in more detail below. It includes an explanation in what way the elements enable for the next milestone.

[52] European Aviation 2040: Challenges of growth, Eurocontrol 2018 (Available at: https://www.eurocontrol.int/sites/default/files/content/documents/official-documents/reports/challenges-of-growth-2018.pdf)



2025

- ECAC-wide implementation of **cross-border Free Route, air-ground** and **ground-ground** connectivity
- Launch **airspace re-configuration** supported by **Operational Excellence** Programme
- Set up an **enabling framework** for **ADSP**, **capacity-on-demand** service and **rewards for early movers**, first ADSP is certified

2030

- Implement **virtual centres** and **dynamic airspace configuration** at large scale
- Gradual transition towards **higher levels of automation** supported by SESAR Solutions
- **Capacity-on-demand** arrangements implemented across Europe
- **New ATM Data service provision model** is implemented across Europe

2035

- Transformation to **flight/flow centric operations**
- **Trajectory-based operations**
- **Service-oriented** air traffic management

Figure 27. High-level transition strategy[53]

By 2025

By 2025, the transition strategy promotes both short term initiatives aimed at addressing the capacity issues expected in the coming years, and initiatives to secure the next steps including structural changes expected to be deployed in the next timeframe 2025-2030.

Milestone	High-level description
1. ECAC-wide implementation of cross-border free route, air-ground and ground-ground connectivity	Air-ground data exchange is essential to increase progressively the level of automation of the ATM systems. Ground-ground interoperability and data exchange are critical to defragment the technical dimension of ATM operations, and thus to move to the ATM data service provision in a virtual centre context. Consequently, the successful and timely deployment of the PCP shall focus on these functionalities, together with the implementation of cross-border and cross-FIR free route airspace and advanced Flexible Use of Airspace.

[53] Source: SESAR JU, 2018

2. Complete airspace re-configuration supported by an operational excellence programme to capture quick wins	Launch airspace re-configuration programme by promoting a collaborative process that would involve all relevant stakeholders. This includes an analysis of areas of inefficiencies at network level, validation activities and delivery of an optimised airspace organisation in compliance with agreed airspace design principles, and based on ECAC wide free-route traffic flows. This new initiative would be complemented by an operational excellence programme, which would aim at identifying best practices and capture quick wins (through changes in operational procedures, rostering, smaller adaptations to systems, etc.) among all stakeholders and effectively support their implementation to reduce delays.
3. Set up an enabling framework for ATM data service providers, capacity-on-demand service and rewards for early movers, first ADSP is certified	Provide guidelines and an appropriate legal framework enabling the set-up of ADSP and the capacity-on-demand service. Encourage willingness to implement the new concepts as soon as they are made available.

By 2030

By 2030, the transition to service orientated architecture is initiated with the implementation of virtual centres providing a better platform for increased interoperability and automation.

Milestone	High-level description
4. Implement virtual centre and dynamic airspace management on a large scale	Building on the new ATM data service provision model, the virtual centre is a key enabler for the resilience of the ATM system. Dynamic management of airspace would already bring benefits when deployed with even more benefits when coupled with optimised airspace organisation and common attributes on how to manage airspace in common. Both SESAR Solutions are expected to be delivered through the SESAR 2020 Programme; their deployment by 2030 is to be secured.
5. Gradual move towards higher levels of automation supported by the implementation of SESAR Solutions	In the context of SESAR 2020, further automation solutions will gradually be made available before 2024. All solutions enabling higher levels of automation will contribute to achieving full trajectory-based operations in the next step. Deployment of these solutions should be incentivised for early movers as referred to in section 5 of this study.

Milestone	High-level description
6. Capacity-on-demand arrangements implemented across Europe	Capacity-on-demand is a complementary service enabling solidarity and cooperative mechanisms between Members States and their designated ANSP to provide additional capacity through re-allocation of controller resources and therefore allowing to operate a more resilient and performing aviation system while keeping a network-centric approach. The service relies on the new ATM data service provision model.
7. New ATM data service provision model is implemented across Europe	The need to access to data services supporting the new architecture will lead to the emergence of new actors. ADSPs will in that timeframe play an important role in supporting the transition towards a more resilient ATM system.

By 2035

By 2035, the transition to the service orientated architecture shall be achieved enabling true Trajectory Based Operations and possibly flight centric control where appropriate.

Milestone	High-level description
8. Transformation to flight centric operations where applicable	Gradual implementation of the flight centric concept where applicable and if proven feasible. This concept is subject to the validation of the SESAR Solution known as "flight centred ATC", which will be supported by relevant ATC tools and system adaptations. The on-going R&D activities aim at assessing the feasibility, confirming the benefits expectations and validating the operating environment.
9. Trajectory-based operations	TBO is central to ICAO and SESAR's vision for efficient and safe ATM operations based on the optimised, accurate and constantly updated trajectory. It includes a list of enablers including sharing of information, adapted processes as well as air and ground system adaptations.
10. Service-oriented ATM	Full implementation of the de-coupling of air traffic services, ATM data services, integration services and geographically fixed services. It is inherent to the structural change of the European ATM system to be more flexible and resilience, and allow for scalability.

6.2 Regulatory enablers

A detailed analysis of the regulatory framework comprising ICAO, SES and EASA rules is presented in Annex F. It includes in particular preliminary considerations related to the notion of a European upper flight information region. Globally, the analysis confirms that the existing regulatory framework can support the transition strategy outlined in the previous section. However, a number of issues are identified where further guidance material or adjustments to the rules would be beneficial; these are detailed below.

6.2.1 Capacity-on-demand service and, more generally, cross-FIR ATS provision

Cross-FIR ATS provision, which is a pre-requisite of both cross-FIR airspace optimisation and the “capacity-on-demand” service is possible within the existing regulatory framework:

- Cross-FIR ATS provision within the same State is a matter for the State and the designated ATS provider to organise, and there is no legal obstacle to overcome.
- ATS provision across national borders is allowed both under ICAO and the SES framework through the certification and designation processes embedded in Articles 7, 8, 9 and 10 of the Service Provision Regulation[54].
- The current arrangements for en-route charging explicitly allow the setting of cross-border charging zones[55], and Article 21(1) of the draft new Commission Regulation on performance and charging schemes[56] even foresees the possibility of en-route charging zones, thus covering the charging aspects of cross-border ATS provision.

A number of issues would however require further consideration:

- In a cross-border ATS provision context, a State’s ability to ensure adequate oversight of the designated service providers, and also liability issues, should be addressed. To this effect, guidance material at European level should be considered.
- Dynamic cross-FIR ATS provision (as required by the capacity-on-demand service) model require a review of regulations covering ATCO licensing and training. . This issue appears to be manageable in an environment with common attributes and tools on how to manage airspace in common as well as a common data layer based on ATM data services.
- While the current arrangements for charging explicitly allow the setting of cross-border charging zones, the issue of calculating the costs, determining the price, and ensuring recovery through charges for capacity-on-demand services require examination. Guidance material at European level would be desirable and, depending on the findings of this examination, a regulatory change may be required.

[54] Regulation (EC) No 550/2004 of the European Parliament and of the Council of 10 March 2004 on the provision of air navigation services in the single European sky (the service provision Regulation)

[55] Commission implementing Regulation (EU) No 391/2013 of 3 May 2013 laying down a common charging scheme for air navigation services (the charging Regulation), Recital 15 and Article 5(4). Also, see Article 21(4) of the draft new Performance and charging Regulation that received a positive opinion from the Single Sky Committee on 17 December 2018.

[56] Which received a positive opinion from the Single Sky Committee on 17 December 2018

6.2.2 ATM data service provision

The existing regulatory framework does not contain obstacles against the creation of ADSPs. Such ADSPs could operate either as a joint venture partnership of existing ANSPs or as a certified external entity providing service in market conditions.

A number of issues would, however, require careful consideration:

- The ATM data services are a currently defined as core part of the ATS. The decoupling of ATM data service provision from ATS provision requires detailed examination of the existing EASA Common Requirements Regulation (EU) No 2017/373[57] to determine the most appropriate organisational and certification requirements for ADSPs that takes due account of the nature of the services including safety and security issues. This examination should also address and provide guidance or regulation on the issue of access to, and ownership of, data.
- Furthermore, a detailed analysis is needed to establish whether and to what extent EU competition law may apply and what would be the consequences. Depending on its outcome, such study may impact the acceptability by stakeholders of the various models identified. This study should be carried out in the light of precedent cases and the recent evolution of the understanding of the EU regulatory context. The study should also weigh up the two trends underpinning the SES legislative packages with on the one hand the connection of ATS provision activities to the exercise of public functions[58] and, on the other hand, the explicit intention within the SES legislative packages to open ANS provision to market conditions[59].

For these reasons, the regulatory and certification framework for ADSPs should be further developed, within both the SES and the EASA regulatory frameworks, to determine the potential application of competition law depending on the model adopted, also taking into account interoperability and performance requirements.

6.2.3 Targeted incentives for early movers

The existing SES framework already contains incentive schemes aiming at supporting a timely and synchronised deployment of technology. In particular:

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[57] Commission implementing regulation (EU) 2017/373 of 1 March 2017 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight, repealing Regulation (EC) No 482/2008, Implementing Regulations (EU) No 1034/2011, (EU) No 1035/2011 and (EU) 2016/1377 and amending Regulation (EU) No 677/2011.

[58] Recital (5) of the service provision Regulation: "*The provision of air traffic services, as envisaged by this Regulation, is connected with the exercise of the powers of a public authority, which are not of an economic nature justifying the application of the Treaty rules of competition.*"

[59] In particular Article 3 of the charging Regulation (EU) No 391/2013. Also, see Article 35 of the draft new Performance and charging Regulation that received a positive opinion from the Single Sky Committee on 17 December 2018, broadening the possibility of submitting Air Navigation Services to market conditions and in particular now explicitly including ATM Data services.

- The existing SES regulations provide several mechanisms to incentivise deployment[60] including modulation of charges to support avionics equipage and different treatment of restructuring costs within the performance scheme [61].
- The Common Project legislation provides public funding via the relevant Union funding Programmes[62], "*to encourage early investment from stakeholders and mitigate deployment aspects for which the cost-benefit analysis is less positive*".
- The European Investment Bank (EIB) has developed a range of financial instruments to support SESAR deployment[63].

However, within the scope of the present study, the scale of the necessary transformation and the need for synchronisation are much greater than for the individual ATM functionalities of common projects. For this reason, it is highly recommended to review the existing incentivisation framework, also using the experience gained from the Pilot Common Project, and to develop and adopt an overall incentivisation policy that will provide genuine incentives to early movers. Examples of possible incentives are provided in Paragraph 5.3 "Targeted incentives for early movers" and their legal aspects are addressed in Annex F, Section F.4.

6.3 Initial considerations on risks areas associated to the initiation of the transition strategy

The proposed transition strategy requires a concerted effort from all stakeholders. This approach will need to focus on building and maintaining consensus for the transition, including adequate change management and risk management process and buy-in from all stakeholder groups including professional staff.

While adequate risk management shall be performed within the context of an implementation plan, some initial considerations regarding key areas of risk associated with the proposed transition have been identified. They are presented below.

Lack of commitment and/or buy-in resulting in delays or inefficient implementation

This new architecture is a substantial change from the way in which ATM has been organised historically. Any change of this nature in a complex and interdependent environment such as ATM embeds risks related to the political commitment and the interest of all parties to act towards the delivery of such changes.

[60] Regulation (EC) No 550/2004 of the European Parliament and of the Council of 10 March 2004 on the provision of air navigation services in the single European sky (the service provision Regulation), Article 15a, and Commission Implementing Regulation (EU) No 409/2013 of 3 May 2013 on the definition of common projects, the establishment of governance and the identification of incentives supporting the implementation of the European Air Traffic Management Master Plan.

[61] Commission implementing Regulation (EU) No 391/2013 of 3 May 2013 laying down a common charging scheme for air navigation services, Articles 7(4) and 16.

[62] Commission implementing regulation (EU) No 409/2013 of 3 May 2013 on the definition of common projects, the establishment of governance and the identification of incentives supporting the implementation of the European Air Traffic Management Master Plan, Recital (20) and Article 13.

[63] See http://www.eib.org/attachments/thematic/air_traffic_management_en.pdf

While the need and urgency to act is clearly identified, there is a need to plan and manage the transition with a very pro-active involvement and engagement of all stakeholder organisations and their professional staff. The incentivisation framework plays therefore a critical role to align the various interest towards the new way of delivering the services. It will also require a proper alignment of the roadmaps established in the European ATM Master Plan together with the implementation of adapted programme management practices to progress towards the proposed target architecture in a coordinated way.

Lack of clear and direct incentives resulting in limited changes at European scale

The approach proposed in the study is building on many examples of good practices that either exist, or are emerging, throughout the European network. Such practices tend however to remain mostly local and rely more on individual organisations' strategy than on explicit external drivers. Consequently, stakeholders implementing solutions such as the one proposed in this study do not necessarily get a positive value recognised at European network level versus others that remain in the mainstream delivery approach resulting sometimes in a "last mover advantage". The rationale for the incentives identified in the study is to change this behaviour in order to scale-up good practices and emerging models of service delivery at European level.

The incentivisation scheme, whether financial or operational, shall be addressed as a priority. It shall be output driven and set-up to deliver sufficient impact to drive organisations behaviour towards the common network objectives.

Slow technology uptake hampers the virtual defragmentation of the European skies

The delivery model proposed in this study for existing ATM services or new ones such as "capacity-on-demand" relies on robust existing technology solutions that have been progressively validated and applied in the field of ATM in particular through the SESAR R&D programme. However, the current cycles of upgrade of the various European ATM components remains very slow and constitutes one of the main risk areas for the successful delivery of additional performance and in particular scalability and resilience.

To accelerate the technology uptake in ATM, alternative options to the current arrangements for technology, systems, products, communication, application and services are proposed through the new architecture which is at the core of this study. Beyond the need for clear incentives as already identified, this will materialise if the regulatory and certification framework applicable (e.g. for dynamic airspace management, ATM Data Service Providers or for capacity-on-demand) evolves in parallel, taking also into account interoperability and performance requirements based on European and ICAO standards. In addition, a number of SESAR Solutions, on which the proposed target architecture beyond 2030 is built, are still undergoing research and development. Their feasibility must still therefore be proven and the associated risks managed accordingly. This must include addressing the cyber resilience risks related to the transition and the need to avoid single points of failure.

Complexity in implementing cross-FIR operations is not overcome and results in sub-optimal airspace configuration

The new airspace system proposed in this study requires a broader European perspective on the provision and organisation of air navigation services. Despite significant progress in cross-FIR and cross-border collaboration on ATM, local or national interests, that can be related, amongst others to performance, liability, or charging implications, can result in a sub-optimal usage of the airspace and management of the European network. Residual risk remains from ongoing research and development of contributing solutions that may appear more complex than foreseen.

To foster such complexity, clear responsibilities should be allocated for the management of EU-wide airspace re-configuration and operational excellence programmes. Consideration can be given as well to the establishment of European guidance material. In addition, when dealing with cross-border airspace configuration, such operations will require a closer collaboration between regulators and a harmonisation of regulatory requirements.

6.4 The human dimension

6.4.1 Expected changes

A key driver of the proposed target architecture is a gradual evolution towards enabling cross-FIR provision of services (be it within the same State, cross-border or even remote) in a free-route cross border airspace, enabled by a progressive increase of controller support, providing ATCOs with tools freeing them from a number of routine tasks and supporting their decision-making.

The gradual implementation of the virtualisation of service provision will allow diversification of the controllers' tasks and the acquisition of new skills and will enable closer collaboration between controllers' teams to address capacity issues. The proposed target architecture enables enhanced collaboration between ATSPs, to bring flexibility to service provision and therefore better align capacity offer to the demand.

The proposed target architecture and associated evolution of service provision will generate changes in the work, skills, and therefore training, of the staff and in particular ATCOs and ATSEPs. However, the human will remain at the centre of the system.

From the perspective of professional staff, the main anticipated changes are:

Group	Main changes
ATCO	Greater operational harmonisation across ANSPs, including a transition to TBO will require evolutionary steps towards the new operational concept. This in turn may require a potential re-distribution of roles within the controller team and greater reliance on datalink as the primary (but not sole) means of controller-pilot communications. More fundamental change would occur where Flight Centric operations are adopted, if proven feasible. Once the automation enablers to provide ATC sector independent are in place, ATCO qualifications will be optimised for a higher number of airspace configurations.
ATSEP	Virtualisation and distributed architecture will have a significant effect on the role of the ATSEP. Data and service assurance from third parties will require new monitoring tools and an even greater emphasis on cyber security. The ATSEP role will evolve to acquire new skills and take on these new responsibilities.
AOC and Pilot	Support increased predictability by updating flight plans prior to flight and the agreed reference trajectory.

Table 6. Impact on professional staff roles

6.4.2 Involvement of staff in the change process

Implementing the proposed target architecture will only be possible by thoroughly involving staff, as the human is the main actor of any change: full involvement, consultation and buy-in of staff in all the phases of the process (set up of the plan, validation activities, and implementation plan) will be the condition for success.

In the SESAR Programme, staff involvement in R&D and validation activities is systematically secured. For the implementation of the proposed target architecture, it is expected that staff will be involved in the relevant preparatory activities leading to the implementation of the transition plan.

Through periodical discussions with trade unions and professional staff associations, in particular in the Sectoral Social Dialogue Committee (SSDC) on ATM and the Expert Group on the Human Dimension of the Single European Sky (EGHD), the European Commission is already informed of the main challenges at stake to properly embrace the human dimension of the evolution of European ATM. Furthermore, the European Commission has expressed an intention to carry out in 2019 an in-depth study on the specific social issues and current and future working environment of Air Traffic Controllers (ATCOs) and Air Traffic Safety Electronics Personnel (ATSEPs) in the European Union. This will address issues of fatigue, stress, responsibility and the physical limits of the human. Such study is certainly likely to support the implementation of the proposed target architecture.

7 High level Impact assessment

7.1 Methodology

The high-level impact assessment is based on a conservative top-down approach relying on simulation results from the Network Manager, SESAR Validation Targets as well as the overall SESAR performance ambition defined in the European ATM Master Plan to ensure the highest level of consistency. Results should be considered as rough order of magnitude estimations and will need further refinement and validation in the future as investment commitments are realised. Further details on the methodology are provided in Annex G.

7.2 Network performance impact

The table below presents the outcome of the high-level network performance impact assessment covering the proposed target architecture and associated transition strategy for the following SES key performance areas (KPA): capacity, environment, cost efficiency and safety at the 2035 horizon.

KPA	Performance impact (order of magnitude)
Capacity	Network is able to accommodate 15,7 million flights (increase of 50% in Network throughput compared to 2017) with delays below or at the level of the agreed SES target (max 0,5 min per flight distributed across all flights)
Environment	Between 240 and 450 kg of CO_2 saved on average per flight due to optimisation of trajectories
Cost Efficiency	Between EUR 57-73 saved per flight due to ANS productivity gains
Safety	All simulations have been done against controller workload and indicate that the same safety levels can be maintained

It is important to note that simulation results taken in isolation show an even more promising potential network performance impact where different aspects of the proposed target architecture where assessed as illustrated below and further detailed in Annex D. For example, zooming in on the KPA for capacity the increase in performance is presented in Figure 28. Average maximum theoretical sector throughput based on simulations below. The middle column corresponds to 2030 and is based on the introduction of ECAC wide cross-border Free Route Airspace (FRA), optimised airspace re-reconfiguration and operational harmonisation including timely deployment of the Pilot Common Project. The right column corresponds to 2035 and includes additional SESAR Solutions that addresses both capacity and system resilience and scalability.

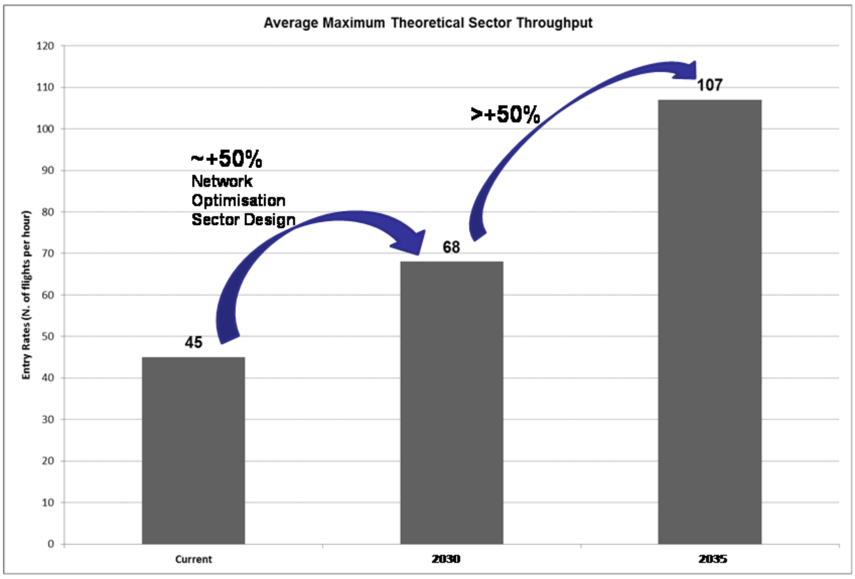

Figure 28. Average maximum theoretical sector throughput[64] based on simulations

Last it is important to note that the insights generated in the study alone do not constitute a sound enough basis to call for an update of the SES High Level goals. It should be noted however that it would be valuable to consider the creation of a specific KPA targeting resilience in future SES Policy orientations.

7.3 Economic impact

Assumptions are needed to translate network performance benefits into net benefits that can be monetised (like delay minutes and fuel savings) taking into account investments needs estimated between EUR 7 and 11 billion over the 2019-2035 period. Assumptions relate for example to the average fleet size, money saved per delay minute, number of sectors, number of ACCs, number of ADSPs, number of ANSPs, fuel burn per nautical mile and price of fuel. All high-level assumptions are specified in Annex G and are consistent with the European ATM Master Plan. The table below summarises the economic benefits per SES key performance area.

KPA	Economic impact (order of magnitude)	Value EUR billion 2019-2035
Capacity	• The increase in capacity, scalability and resilience linked to the timely implementation of the proposed transition strategy is estimated to bring 476 million of delay minutes saved between 2019 and 2035. • The additional impact on potential flight cancelation avoidance was not quantified due to lack of reliable data.	34

[64] Source: Eurocontrol/Network Manager, 2018

Environment	• Based on results from simulations conducted by the Network Manager, it has been estimated a reduction of Nautical Miles (NM) flown between 4 and 10 NM in 2030 and between 7 and 13 NM in 2035. Considering the projected traffic forecast up to 2035, and linear increase in the reduction of NM saved, the total benefits is estimated between 30 and 60 millions of tons of C02 corresponding EUR 3-6 billion over the 2019-2035 time period.	**3-6**
Cost efficiency	• Cost efficiency estimates include ANS productivity gains related to an increase of average sector load thanks to the introduction of operational harmonisation and productivity tools for the controller. • Collectively, total ANS productivity benefits are estimated to amount to EUR 5-7 billion. over the 2019-2035 period	**5-7**
Safety	• No economic assessment was performed	**N.A.**

7.4 Bringing the picture together

The key simulation result from the Network Manager is that current arrangements for capacity enhancement would lead to severe network congestions and average delay of up to 8.5 minutes per flight in 2035. Implementing the proposed target architecture (including the airspace optimisation and operational harmonisation) would bring delays back in line with the SES target (0.5 minutes average en-route delay per flight). The main benefit is therefore avoiding the high cost of delay; a conservative estimate of this benefit is EUR 34 billion. There are additional benefits realised through increased ANS productivity of EUR 5-7 billion and a significant decrease in the environment footprint of aviation (monetised at EUR 3 to 6 Bn).

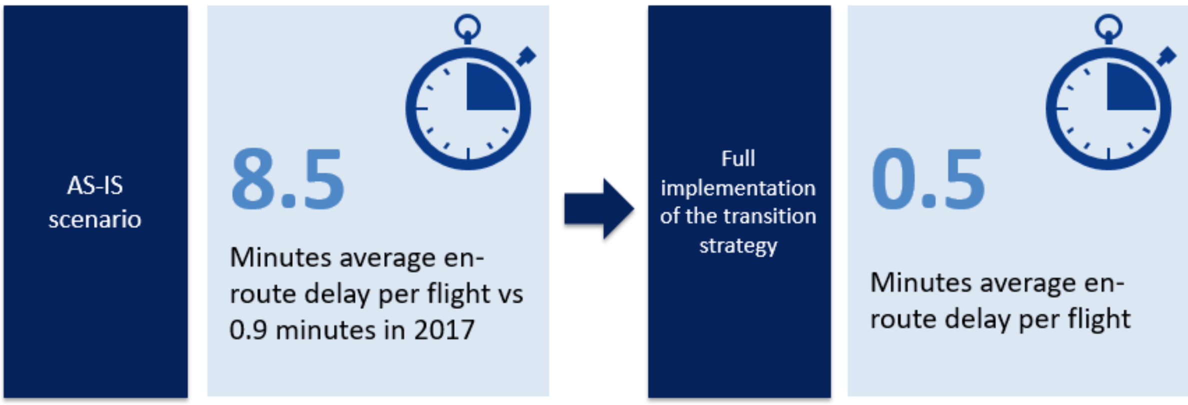

Figure 29 Key delay statistics from simulations conducted by the Network Manager

The overall results of the economic analysis indicate a considerable potential to realise a net benefit of EUR 31-40 billion (or EUR 13-17 billion in NPV) over the 2019-2035 period. A sensitivity analysis was conducted to test the robustness of the economic analysis under different assumptions (addressing main areas of uncertainty linked to simulation results, traffic forecasts and investment estimations). Details on the sensitivity analysis are available in Annex G, section G.6.

The impact assessment results are sufficient to demonstrate that investing in a solution to the anticipated capacity issues is essential for the future of European aviation.

8 Recommendations

In order to initiate the transition towards a **Single European Airspace System**, the following three recommendations should be considered by the Commission.

Firstly, in addition to the timely rollout of the first SESAR R&D results (Pilot Common Project) there is a pressing need to implement additional measures covering airspace optimisation and operational harmonisation to contain the current capacity crisis.

Recommendation 1: Launch airspace re-configuration supported by an operational excellence programme to achieve quick wins
The Commission is encouraged to: • Launch an EU-wide airspace re-configuration programme in which the Member States, Network Manager, air navigation service providers, civil airspace users and military should work together to define and implement an optimal cross-FIR and flow-centric redesign of airspace sectors. This optimised airspace design should be consistent with already agreed-upon design principles at European level. • Launch an EU-wide operational excellence programme in which the Network Manager, air navigation service providers, civil airspace users, military and staff associations should work together to achieve operational harmonisation aligning on air control centres capacity and ways of working to best practices through systematic operational excellence throughout the Network.

Secondly, this study has demonstrated that increased automation and virtualisation hold the greatest promise for enabling a collaborative approach to ensuring higher levels of resilience. This is an important evolution that operational stakeholders and the supply industry have already been partly anticipating resulting in the emergence of a number of industry-based alliances irrespective of national borders or FABs. These forms of cooperation should be encouraged, as they are an effective vehicle to realise the Single European ATM System.

Recommendation 2: Realise the de-fragmentation of European skies through virtualisation and the free flow of data among trusted users across borders
The Commission is encouraged to: • Review policy options which, on their own or in addition to FABs, could effectively deliver a virtual defragmentation of European skies and potentially generate higher levels of resilience by encouraging industry-based alliances to deliver core interoperability through common service delivery. • Implement a certification and economic framework for ATM data services providers taking also into account possible restructuring of ANSP services as well as an EU framework for on-demand cross-border use of services (capacity-on-demand). • Continue to support timely delivery of SESAR solutions contributing to the delivery of the proposed target architecture.

Thirdly, based on the analysis conducted in this study, it is concluded that financial incentives may be necessary to encourage early movers and promote the shift towards the target architecture.

Recommendation 3: Create a legal and financial framework that rewards early movers
The Commission is encouraged to review its incentivisation policy to reward actors who are the first to implement the high-level milestones identified in the proposed transition strategy.

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Annex A Glossary

AAS	Airspace Architecture Study
ACC	Air control centre
A-CDM	Airport collaborative decision making
ADS-B	Automatic dependent surveillance - Broadcast
ADSP	ATM data service provider
A-FUA	Advanced flexible use of airspace
A/G	Air/Ground
AIM	Aeronautical information management
AIRAC	Aeronautical information regulation and control
AIS	Aeronautical information services
ANS	Air navigation service
ANSP	Air navigation service provider
AOC	Airline operational control
ASM	Airspace management
ATC	Air traffic control
ATCO	Air traffic controller
ATFCM	Air traffic flow and capacity management
ATFM	Air traffic flow management
ATM	Air traffic management
ATN	Aeronautical telecommunications network
ATS	Air traffic services
ATSEP	Air traffic safety electronics personnel
ATSU	Air traffic service unit
AU	Airspace users
CANSO	Civil air navigation services organisation
CBA	Cost benefit analysis
CD&R	Conflict detection and resolution
CFMU	Central flow management unit
CNS	Communications, navigation and surveillance
COM	Communication
COOPANS	An international partnership between the air navigation service providers of Austria (Austro Control), Croatia (Croatia Control), Denmark (Naviair), Ireland (Irish Aviation Authority), Portugal (NAV Portugal) and Sweden (LFV).
CPDLC	Controller-pilot data link communications
DSNA	Direction des services de la navigation aérienne
EAD	European AIS database
EASA	European aviation safety agency
EC	European commission
ECA	European court of auditors
ECAC	European civil aviation conference
EFPL	Extended flightplan
EGHD	Expert group on the human dimension of the single European sky

EIB	European investment bank
EPP	Extended projected profile
EU	European Union
EUIR	European upper flight information region
FAB	Functional airspace block
FDPS	Flight data processing system
FIR	Flight information region
FRA	Free route airspace
FUA	Flexible use of airspace
FMS	Flight management system
GNSS	Global navigation satellite system
HMI	Human machine interface
IATA	International air transport association
ICAO	International civil aviation organisation
IFR	Instrument flight rules
IP	Internet protocol
KPA	Key performance area
MET	Meteorology
MONA	Monitoring Aids (for monitoring conformance with ATC instructions)
MTCD	Medium term conflict detection
MSP	Multi sector planner
NAV	Navigation
NM	Network manager
NOP	Network operations plan
NPV	Net present value
OLDI	On-line data interchange
PCP	Pilot common project
PRB	Performance review body
RCP	Required communications performance
RVSM	Reduced vertical separation minima
R&D	Research & development
SEAS	Single European Airspace System
SES	Single European Sky
SESAR	SES ATM Research
SJU	SESAR Joint Undertaking
SSDC	Sectoral Social Dialogue Committee
STATFOR	Statistics and Forecasts service
STCA	Short term conflict alert
SUR	Surveillance
SWIM	System wide information management
TBO	Trajectory based operations
UAC	Upper area control centre
VDL/2	VHF datalink mode 2
VFR	Visual flight rules

VHF	Very high frequencies
WOC	Wing operational centre
4D	4 dimensional

Annex B References

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Annex C Simulations conducted by the Network Manager

C.1 Purpose of simulations

The simulations conducted by the Network Manager aim at providing a view on how the delays would evolve looking over the next 15–20 years (snapshots at horizons 2030 and 2035).

They also illustrate some of the possible benefits of the available solutions discussed in the scope of the two focus areas addressing the capacity issue, namely:

- cross border European Civil Aviation Conference (ECAC) wide Free Route Airspace,
- alignment of Area Control Centre (ACC) productivity to observed best-practices,
- airspace reconfiguration and;
- a subset of automation solutions increasing Air Traffic Control Officer (ATCO) productivity.

The Network Manager (NM) has used its NEST[65] and CAPAN[66]tools, following the methodology commonly applied for airspace design studies[67]including capacity planning and sector capacity assessments[68]in support of the ANSPs of the European ATM network.

Details on the data tools and processes used by the Network Manager in can be found in section 3.3 of the Network Operations Plan.

The three different simulations conducted are the following:

- **AS-IS** simulation**:** Illustrates the expected evolution of capacity and delays taking into account know deployment commitments such as the timely deployment of the Pilot Common Project (PCP) and known airspace changes reflected in the Network Operations Plan at the 2022 horizon
- **Run 1 simulation:** Simulates the effect of the generalisation of ECAC wide cross-border Free Route Airspace (FRA), optimised airspace re-reconfiguration across ECAC, upward-alignment of ACC capacity to the level of currently well-performing ACCs (taking into account performant operating practices and local system support) and timely deployment of Pilot Common Project.
- **Run 2 simulation:** Includes the assumptions and changes included in Run 1 and in addition takes into account the benefits brought by a subset of SESAR 2020 solutions as well as datalink as primary mean for air/ground (A/G) communication (considering 90% of aircraft equipped).

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C.2 Simulation Assumptions

C.2.1 Common Assumptions

The following assumptions apply to all simulations:

- Simulations cover the European ATM network including all the European Union's 28 and Eurocontrol's 41 Member States, as well as others, which have bilateral agreements with the Network Manager.
- Simulations have been made at horizon 2030 and 2035.
- The simulations do not include military zones and activities.
- Air traffic is predicted between all city-pairs based on the following assumptions:
    - Future Air traffic simulations are made starting from a busy summer day starting from actual traffic observed on September 9, 2016, with 34,594 flights in the NM reference area.
    - Traffic forecast uses the latest Eurocontrol Network Manager Seven-Year Forecast[69], covering the period 2018-2024.
    - After 2024, the traffic was calculated by extrapolating the high growth scenario traffic increase foreseen between 2023 and2024. As such, a yearly traffic growth of 3.1% was considered for the entire period 2024-2035.
    - The calculation of the traffic demand follows the same procedure as for the Network Operations Plan and as described in the agreed capacity planning process
    - Known airport capacity plans have been taken into consideration and the traffic distribution was based on the shortest routes scenario.

ECAC		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	AAGR 2018-2024	RP2 2015-2019 AAGR	RP3 2020-2024 AAGR
IFR Flight Movements (Thousands)	H	.	.	.	.	11,089	11,494	12,036	12,425	12,836	13,255	13,669	**3.7%**	**3.3%**	**3.5%**
	B	9,770	9,923	10,197	10,604	10,957	11,245	11,524	11,738	11,969	12,176	12,405	**2.3%**	**2.9%**	**2.0%**
	L	.	.	.	.	10,826	10,995	11,058	11,095	11,176	11,226	11,300	**0.9%**	**2.4%**	**0.5%**
Annual Growth (compared to previous year unless otherwise mentioned)	H	.	.	.	.	4.6%	3.6%	4.7%	3.2%	3.3%	3.3%	3.1%	**3.7%**	**3.3%**	**3.5%**
	B	1.7%	1.6%	2.8%	4.0%	3.3%	2.6%	2.5%	1.9%	2.0%	1.7%	1.9%	**2.3%**	**2.9%**	**2.0%**
	L	.	.	.	.	2.1%	1.6%	0.6%	0.3%	0.7%	0.4%	0.7%	**0.9%**	**2.4%**	**0.5%**

Table 7. Annual traffic growth values[70]

The choice of the high traffic growth scenario was made to ensure that capacity delivery covers a demanding scenario and that, in the longer term, the capacity provision will be able to anticipate increasing traffic demand.

[69] Eurocontrol Seven-Year Forecast February 2018 (Available at: https://www.eurocontrol.int/publications/eurocontrol-seven-year-forecast-february-2018)

[70] Eurocontrol Seven-Year Forecast February 2018 (Available at: https://www.eurocontrol.int/publications/eurocontrol-seven-year-forecast-february-2018)

C.2.2 Specific assumptions for the AS-IS simulations

The following assumptions were used for the AS-IS simulation:

- All ACCs included in the April 2018 approved version of the Network Operations Plan (NOP) 2018-2019/2022[71] were considered as part of the simulations
- All evolutions related to PCP deployment and other major projects as covered by the local plans provided for the NOP by the Air Navigation Service Providers (ANSPs) and as reflected in the April 2018 approved version of the NOP 20189-2019/2022 were included.
- For ACC capacity plan:
    - Up to 2022, the latest NOP ACC capacity plans were taken into consideration, as per the April 2018 approved version of the NOP 2018-2019/22
    - After 2022, ACC capacities were calculated from current ACC capacity with a +2% and +3% yearly growth for saturated and non-saturated ACCs respectively. As such,
    - For the ACCs that have an annual delay forecast at 0.05 minutes/flight or lower for the year 2022, an yearly capacity increase of 3% was considered as being feasible;
    - For the ACCs that have an annual delay forecast higher than 0.05 minutes/flight for the year 2022, an yearly capacity increase of 2% was considered as being feasible, due to the level of saturation starting to be reached in elementary sectors.
    - As a result, for the period 2022-2030, a capacity increase of 3% per year was applied for 36 ACCs and a capacity increase of 2% per year was applied for 29 ACCs.
- No additional network-orientated implementation of operational and technical improvements was included.

In short, the AS-IS simulation considers **the current airspace organisation** and **does not include impact of SESAR technology apart from those included in the PCP.**

C.2.3 Specific assumptions for Run 1

Run 1 simulations include

- ECAC wide cross-border FRA as from 2025 and implementation down to terminal manoeuvring area (TMA) levels (as shown in Figure 30);
- optimised airspace re-configuration across ECAC;
- network-orientated implementation of operational and technical improvements;
- upward-alignment of ACC capacity to the level of currently well-performing ACCs (taking into account performant operating practices and local system support);
- timely deployment of Pilot Common Project.

[71] European Network Operations Plan 2018-2019/22, Network Manager, 3rd July 2018 (Available at: https://www.eurocontrol.int/publications/european-network-operations-plan-2018-2022)

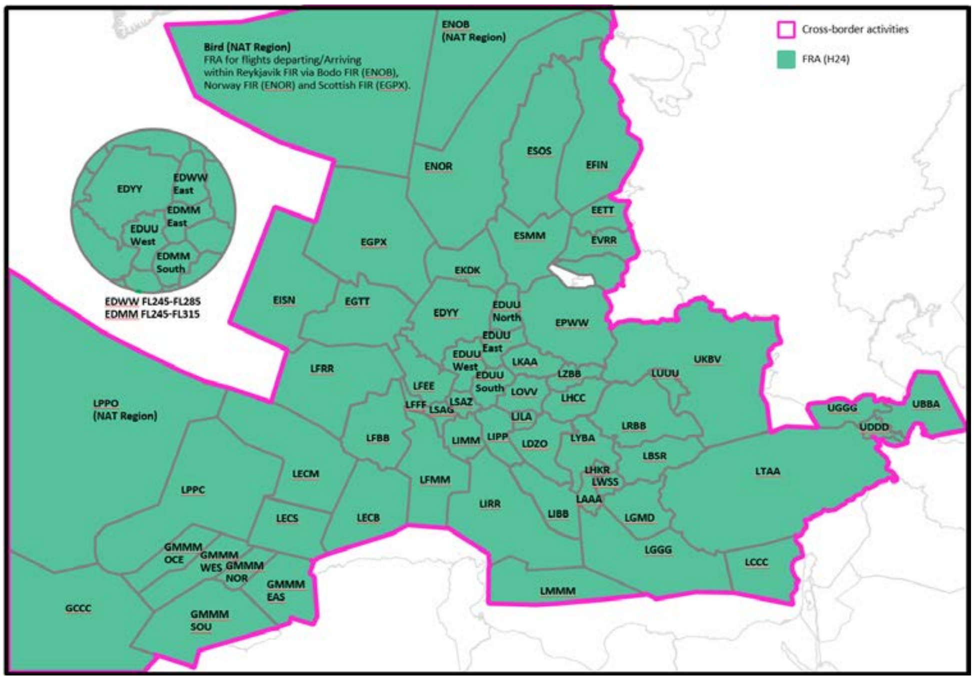

Figure 30. Visualisation of FRA in Run 1 after 2025[72]

C.2.4 Specific assumptions for Run 2

Run 2 simulations include all improvements included in Run 1 plus additional benefits brought by a subset (for which the impact on controller productivity could already be quantified) of SESAR 2020 solutions further described in Annex E and the use of datalink as primary mean for A/G communication (assuming 90% equipage rate).

ATCO workload model for Run 2

The workload model applied for Run 2 is the same for all ECAC ACCs. It is based on a well performing European ACC an advanced ATM system and supporting tools, modern operational procedures and high complexity traffic.

This model has been adapted to incorporate the impact of the SESAR Solutions selected for the simulations. Indeed, NM and SESAR JU experts identified the group of tasks performed by the controller that would be impacted by the SESAR solutions; then NM experts conducted an expert evaluation to assess the quantitative impact of these SESAR solutions on the tasks or group of tasks performed by the controllers. This exercise produced the capacities of each individual sector or in various configurations. The final sector capacities have been established only after several iterations.

[72] Source: Eurocontrol/Network Manager, 2018

C.3 Methodology

This section describes the process used to define the airspace organisation used for the run 1 & 2.

C.3.1 References for methodology

The en-route Air Traffic Flow Management (ATFM) delay forecast was executed on the basis of the methodology described in the agreed capacity planning process provided in the Annex 1 to the European Network Operations Plan 2013-2015 – Edition June 2013 - Capacity Assessment and Planning Guidance.[73] The same methodology is used for performing en-route ATFM delay forecasts for each edition of the Network Operations Plan.

C.3.1.1 Implementation of changes related to airspace structures

The airspace structures are from Aeronautical Information Regulation And Control (AIRAC)1701 modified by available planned airspace improvements up to end of reference period (RP) 3 as per two editions of the European Route Network Improvement Plan (ERNIP) Part 2 - ATS Route Network (ARN) Version 2017-2021 and ARN Version 2018-2022[74].

The airspace structures as included in the NEST layers were changed so as to simulate full cross border Free Route Airspace implemented (situation as of end of RP3).

Entry/exit points in/out of the FRA area were placed at the border of the study reference area. All intermediate points, inside the FRA area, were kept as they existed on AIRAC 1701. Arrival and departure points were kept to provide connectivity between en-route airspace and airports.

Airspace restrictions were not considered in the study and all evaluations were made with no military activity to preserve comparability of the results.

To arrive at the study reference area some 29,000 modifications were implemented to the airspace structure of AIRAC 1701. A snapshot of the layers of airspace changes introduced in the study is shown in the Figure 31 below:

[73] European Network Operations Plan 2013-2015 – Edition June 2013
[74] ERNIP Part 2 - ARN Version 2017-2021

Figure 31. Example of airspace layer changes made for the study[75]

C.3.1.2 Set up of airspace organisation used for Run 1 & 2

Methodology and Criteria

The methodology and criteria used are those described in the European Route Network Improvement Plan – Part 1 - European Airspace Design Methodology - General principles and technical specifications for airspace design. [76]

Definition of Sector Groups

The principles for defining sector groups are described below and illustrated in Figure 32 and Figure 33.

[75] Source: Eurocontrol/ Network Manager, 2018
[76] European Route Network Improvement Plan – Part 1 – European Airspace Design Methodology – General principles and technical specifications for airspace design

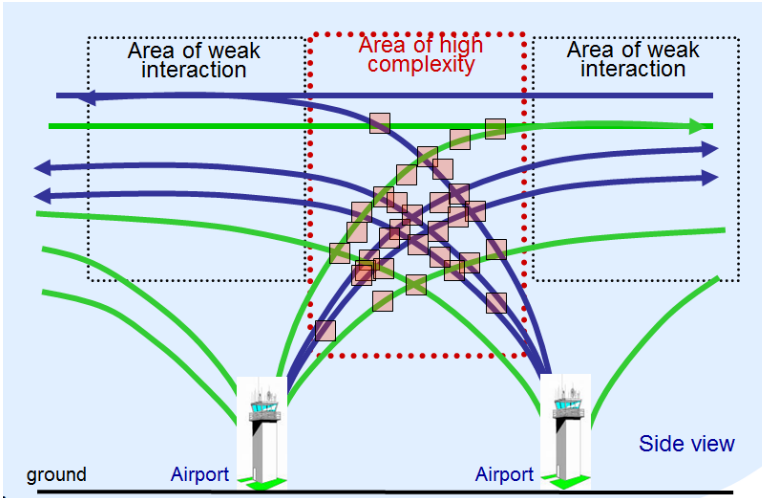

Figure 32. The principles for defining sector groups[77]

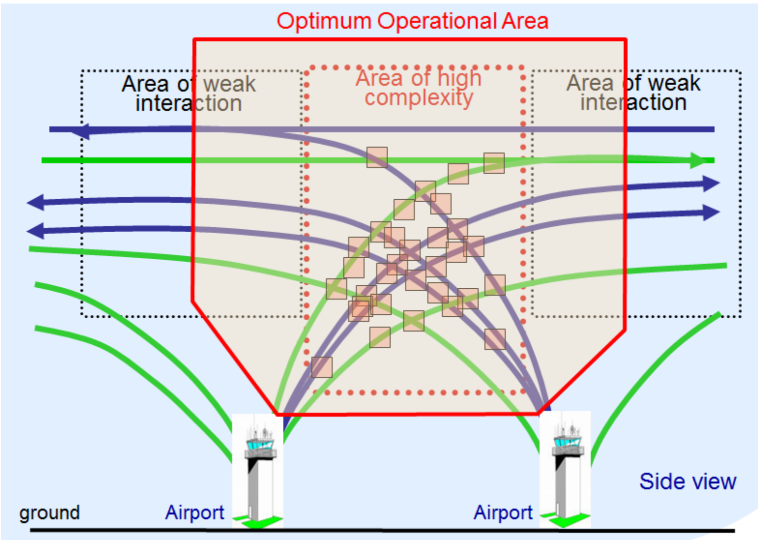

Figure 33. The notion of optimum operational area[78]

The General Criteria for determining Sector Groups are based on the notion of areas of weak and strong interaction that help in defining its boundaries. Areas of strong interaction are likely to occur in airspace where the ATC task is more complex due to one or more influencing factors including; high traffic density, nature of traffic, number of conflict or crossing points, airspace restrictions. Areas of weak interaction would occur in airspace where there are fewer conflicts, traffic is mainly stable and the ATCO tasks less complex.

[77] Source: Eurocontrol/ Network Manager, 2018
[78] Source: Eurocontrol/ Network Manager, 2018

The definition of sector groups must be based on an optimised airspace structure, integrating all the airspace components (FRA, route network, supporting sectorisation, multiple route options and associated, etc.). It must also take full account of military operational requirements. Particular emphasis should be given to the efficient connectivity with terminal airspace. Sector groups should contain elementary sectors with strong/complex interaction that necessitate close coordination between controllers.

The criteria to define Sector Groups are a combination of traffic density, nature of traffic (climbing/descending) and airspace topology (crossing flows, close crossing points). Within a Sector Group, several different combinations of sectors (sector configurations) are possible, depending on traffic flows.

Weak interaction between sector groups are the zones of reduced complexity, where there are fewer conflicting flows and less evolving traffic. In areas of high traffic density and high complexity where there is no obvious area of weak interaction, it might be necessary to artificially create these zones to permit the definition of a Sector Group where appropriate (as is often done at the Flight Information Region (FIR) borders, to facilitate inter-centre coordination). Such artificial creation has impact on operational performance.

The following Specific Criteria are applied for the establishment of Sector groups:

- The borders of sector groups should be based on operational requirements and do not to coincide vertically.
- Sector Groups should be designed to enable sufficient distance for conflict resolution in all routing options.
- Traffic profiles should be of a similar nature as far as possible. (evolving, in level flight etc.)
- It is not an essential requirement to envelop segregated airspace within one Sector Group. However, the primary route and the alternate option should, in general, be contained within the same Sector Group to capitalise on the potential for flexible re-routing.
- The Sector Group should be configured to contain the traffic for sufficient time to be operationally practical.
- The Sector Group should be configured to allow for flexible sector configuration
- Conflict points situated in close proximity to each other should be contained in the same Sector Group but ideally not in the same sector.
- A Sector Group should have an operationally manageable number of sectors, likely to be 4/6 sectors in the congested areas and 6/8 sectors in the other areas.
- Similarly, average time flown within a Sector Group should not be too excessive to fit the general criteria on optimal numbers of sectors.
- Vertical limits of the sector groups will vary according to their location and to the type of traffic contained within.

Overall methodology

The overall methodology is summarised in the Figures 5 and 6. For the purpose of this study, the Traffic Flow Families has been replaced by Operational Optimum areas and the sectors were designed within these optimum areas.

Targeted Studies aiming at operational implementation, would be more detailed and would require the proper definition of Traffic Flow Groups. They correspond to the sector groups as defined in the European Route Network Improvement Plan – Part 1 - European Airspace Design Methodology - General principles and technical specifications for airspace design.

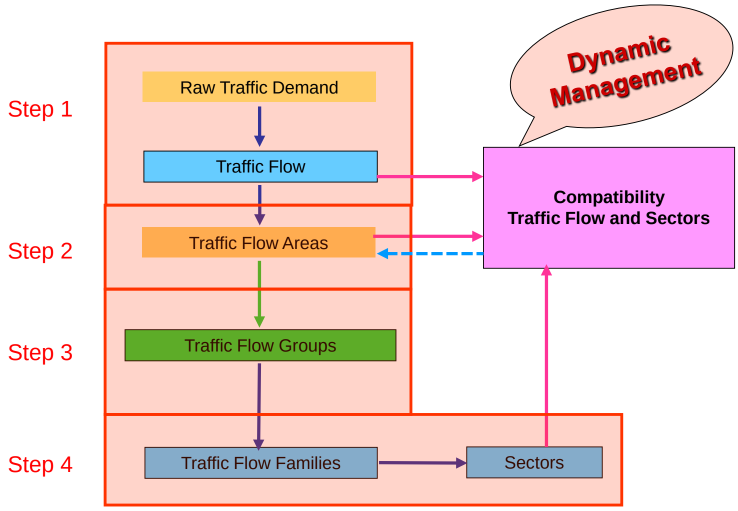

Figure 34. Steps in the methodology[79]

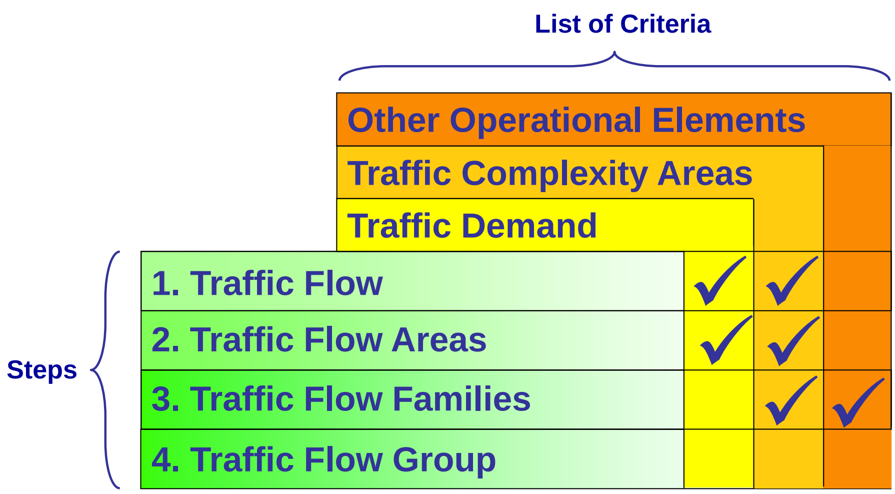

Figure 35. The application of criteria in the different steps[80]

[79] Source: Eurocontrol/ Network Manager, 2018
[80] Source: Eurocontrol/ Network Manager, 2018

Application of Methodology and Criteria

The traffic sample, assigned between the city pairs on the shortest distance and through the full cross border FRA, was analysed along the following criteria:

- All traffic flows were considered, within, to/from or overflying the NM area
- Traffic density – the traffic density was considered as one of the criteria in defining the next steps in the airspace design process, as described above. Traffic density is presented as a number of aircraft during the 24 hour period inside a quadrant of the following dimensions: 10x10NMx2FL.

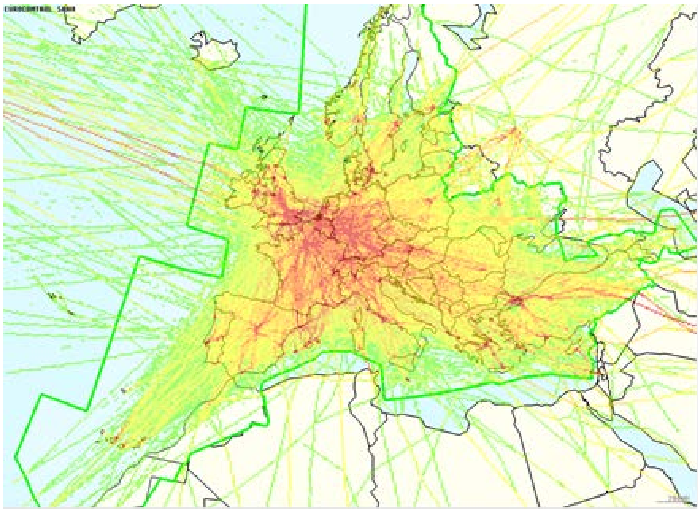

Figure 36. Air traffic density over Europe in the simulation sample[81]

Traffic conflicts – the potential traffic conflicts were considered as other criteria in defining the next steps in the airspace design process, as described above. A Traffic conflict is determined by a flight path intersecting with another flight path. The conflicts are not distinguished by type (crossing altitudes, crossing tracks, etc.); they are only depicted as point with the location of its occurrence. The airspace design solutions and the supporting procedures and systems are expected to safely address those potential conflict areas. Figure 37 below shows the spots of high traffic conflicts.

[81] Source: Eurocontrol/Network Manager, 2018

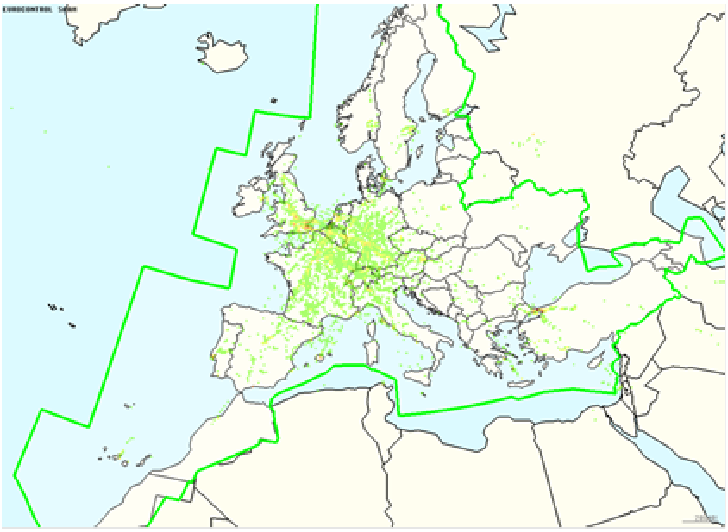

Figure 37. Areas with every-day high numbers of potential traffic conflicts[82]

Complexity areas – The areas of high complexity, depicted on the Figure 9 below, correspond to the high traffic density areas combined with the conflict areas. The combination of density and a number of conflicts is given per quadrant of the following dimensions: 10x10NMx2FL (flight levels), where every conflict is weighed two times the number of aircraft (C=d+2c; C=complexity; d=traffic density; c=traffic conflict).

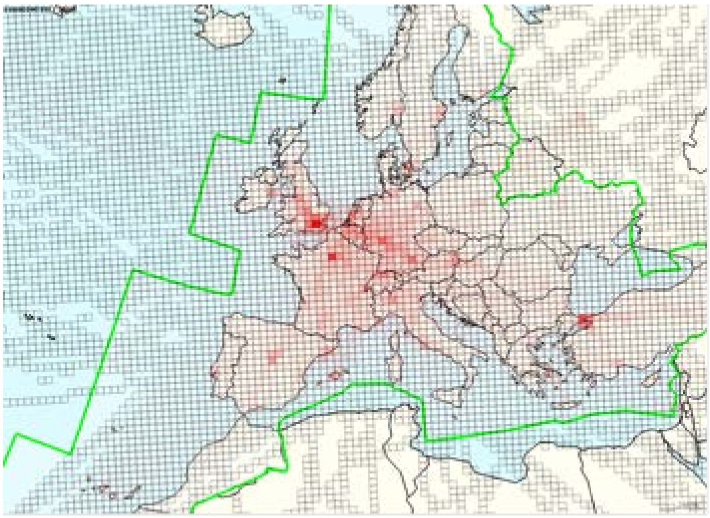

Figure 38. Areas of high traffic complexity[83]

[82] Source: Eurocontrol/ Network Manager, 2018
[83] Source: Eurocontrol/ Network Manager, 2018

Traffic demand and distribution

The overall traffic distribution based on seamless FRA implementation as described above and shown in Figure 39 below:

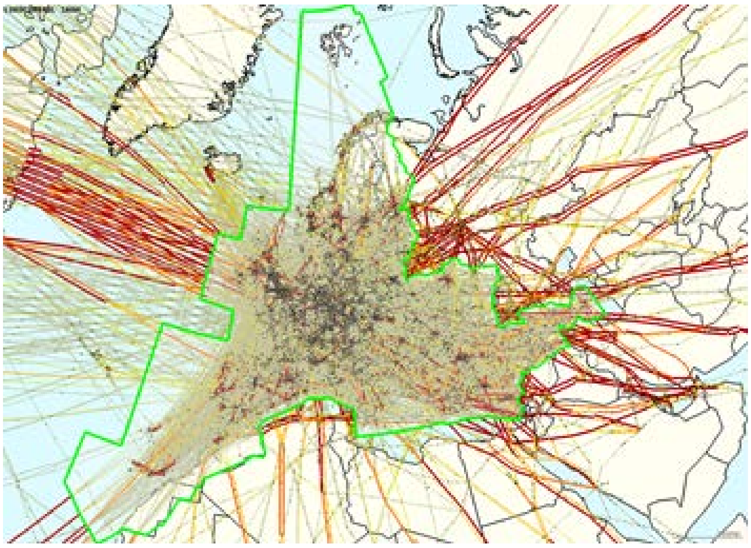

Figure 39. Overall traffic distribution based on seamless FRA implementation[84]

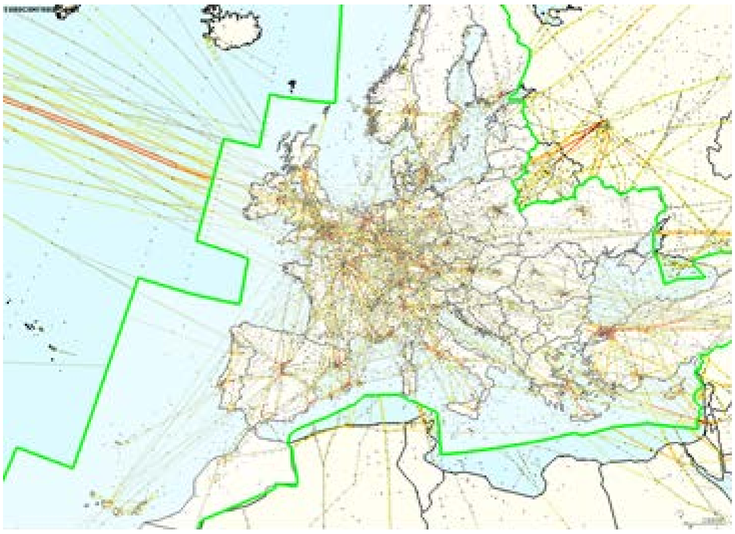

Figure 40. Visualisation of city pair routes[85]

The assignment of raw traffic demand between the city pairs as shown in Figure 40 was based on the shortest distance within the seamless FRA to analyse the traffic distribution across the NM reference area.

[84] Source: Eurocontrol/Network Manager, 2018
[85] Source: Eurocontrol/Network Manager, 2018

Analysing traffic distribution resulted in identifying major entry/exit areas on the border interface of the FRA area (gateways), as well as within the area itself (connectivity to major TMA areas). Figure 41 below shows the gateways (red circles) and internal node areas (blue circles).

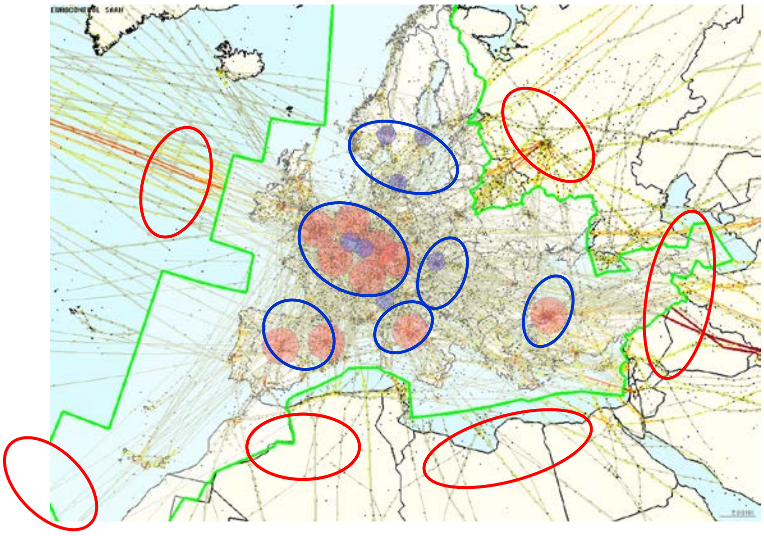

Figure 41. Major entry/exit areas inside and at the interface of the FRA area[86]

The gateways correspond to the intersection of major traffic flows with the interface between the NM reference area and adjacent areas. The Gateways have a symbolic meaning since traffic is allowed to cross the interface at any entry/exit point on the border. A gateway encompasses several entry/exit points used by majority of flights entering from or exiting to the same region.

The internal node areas are associated to areas where the prevailing traffic is that operating to/from major airports in the corresponding area. Those areas group several TMAs from major airports and are defined as Terminal Airspace Systems (TAS).

Indeed, to improve the design and management of terminal routes and ATC sectorisation servicing several airports in close proximity, the fusion of two or more terminal airspace structures has been envisaged and has been called terminal airspace system. TASs could extend across national borders if required by operational requirements. Operations within a TAS should be systematised and characterised by systems of entry (arrival) and exit gates that accommodate flows of arrivals and departures to and from various runways/airports. Generally, these entry and exit gates are to remain fixed even when the airspace configuration changes.

Creation of Traffic Flow Areas

Air traffic flows are the consequence of the traffic distribution in relation to gateways on the border interface of the FRA area, as well as within the FRA area TAS. A traffic flow, in the context of this study, is a set of flights with similar elements with strong geographical connotation, e.g. orientation of flight trajectories and their proximity relative to their current geographical area, flights originating

[86] Source: Eurocontrol/Network Manager, 2018

from the same area/region and proceeding in similar directions, or flights on the similar tracks proceeding to destinations in the same area/region. The major traffic flows are shown in Figure 42.

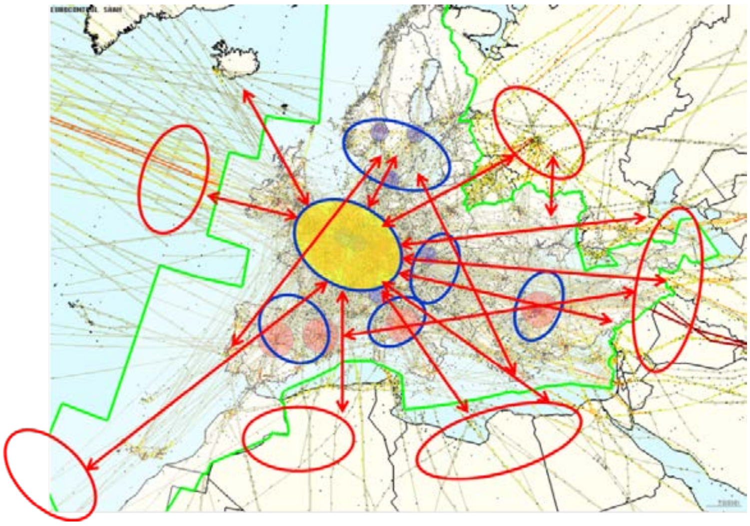

Figure 42. Identification of major traffic flows[87]

It can be noticed that central TAS coincides with the central Traffic Flow Area (TAF), because the majority of traffic flows finish or start from the central TAS. Further to that, there is relatively intense traffic inside the central TAS not leaving the area.

Creation of Optimum Operational Areas

On the basis of the criteria for the creation of the sector groups, the Optimum Operational Areas (OOA) are including main traffic flows, but with the borders defined after being analysed along the following criteria:

- traffic density,
- traffic conflicts,
- traffic complexity, and
- low interaction areas.

The analysis focused specifically on the traffic orientation, traffic loads, and most importantly, traffic interactions on the respective borders. The OOA definition and fine-tuning was done after multiple iterations by applying a mathematical model available in SAAM/NEST involving the application of the traffic density and complexity criteria defined above.

The OOAs are volumes of airspace with balanced traffic loads, which would allow for collaborative management of operational constraints in a manner to balance operational efficiency by defining the operational sectors. They correspond to a theoretical intermediate step leading to the design of operational sectors.

Optimum sector design

Sectors defined within each OOA presented in this study are the elementary sectors being the primary operational constituents of an airspace structure. This means that each of the defined

[87] Source: Eurocontrol/Network Manager, 2018

sectors can act as the operational volume of airspace on its own or combined (collapsed) with other sectors. Each of the elementary, spatial sectors is represented by a dedicated technical sector suite (usually a pair of controller working positions (CWPs)) while operational. It is assumed that each sector suite should be manned by two ATCOs while operational during at least twelve-hour period per day. By the application of the new technologies and advanced ATM system functionalities, it may be considered that, at average, less than two ATCOs will be manning an operational sector in the future. In particular, the move towards a flight or flow-centric air traffic control, and the application of trajectory based tools will inevitably allow the introduction of a multi-sector planner reducing a number of ATCOs required to generate maximum sector configuration for a given ATS unit.

Sector capacities in the new airspace organisation

The sectors defined as explained above have been subject to a Air Traffic Control (ATC) Sector Capacity Analyser (CAPAN) assessment by applying the same CAPAN parameters through the entire geographic scope of the study. The workload model applied was based on a well performing ACC in Europe an advanced ATM system, modern operational procedures and high complexity traffic. This exercise produced the capacities of each individual sector or in various configurations. The final sector capacities have been established only after several iterations. The result of these interactions provides the given number of sectors per OOA, i.e. maximum number of sectors needed to handle the daily traffic load. The sector elements with their respective calculated capacities have been run in NEST to determine the collapsed sectors and their capacities. The Improved Configuration Optimiser (ICO) model has been applied to produce the opening schemes.

The total number of sectors resulting from the re-design is slightly less than the number of sectors operated simultaneously today. With these sectors, the traffic increases up to 2025 can be handled at a delay per flight of approximately 0.45-0.5 minutes/flight. Further sectorisation actions are still possible to bring the number of sectors to the one or slightly above those handled today (approximately 700-750 sectors simultaneously opened) and to maintain a delay per flight at approximately 0.5 minutes.

The above total number of sectors includes the entire airspace, from Surface (SFC) to FL660, excluding TMAs. The TMA's dimensions and shapes, as well as their contents, have been kept unchanged.

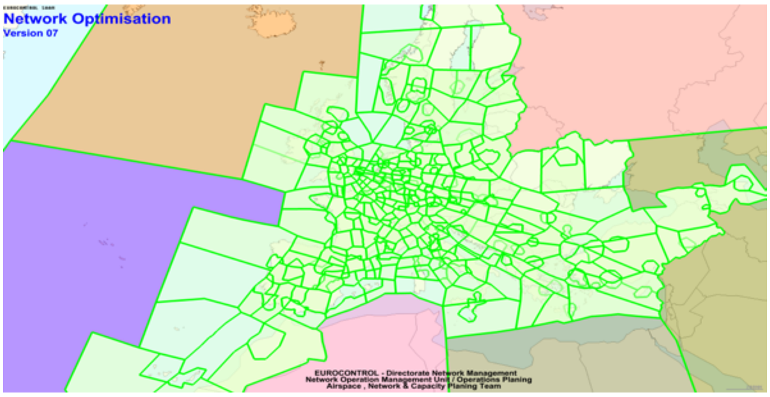

Figure 43. Illustrative result of sectorisation re-design considering network optimisation[88]

[88] Source: Eurocontrol/Network Manager, 2018

C.4 Simulation Results

C.4.1 Results of AS-IS simulations

For 2030

As the delay forecast increased to significantly high levels for a number of ACCs, the delay forecast was frozen at 4 minutes/flight for the summer season for 24 ACCs. Indeed, exaggerated high delays would have resulted t in significant traffic disruptions, network effects and major re-routing actions would have been taken to limit the operational disruptions. Based on the assumptions above, the delay forecast for the year 2030 indicates an annual delay per flight of **6.23 minutes/flight**.

- At European level, only 24 ACCs (most of them located at the edges of the European airspace) are still expected to have an operationally acceptable performance:
- 8 ACCs will record an en-route annual delay per flight of up to 1 minute/flight,
- 4 ACCs will record an en-route annual delay per flight between 1-2 minutes/flight,
- 24 ACCs will record an en-route annual delay per flight between 2-3 minutes/flight and
- 5 ACCs will record an en-route annual delay per flight between 3-4 minutes/flight.

The significant delay impact is also expected to have consequences on the flight efficiency. The evaluation of such consequences has been estimated on the basis of the actual route extension during a high delay day in the network with a low delay day in the network. Such a difference is estimated to be approximately 4 NM/flight.

For 2035

As the delay forecast increased to significantly high levels for a number of ACCs, the delay forecast was frozen at 5 minutes/flight for the summer season for 28 ACCs.
Based on the assumptions above, the delay forecast for the year 2035 indicates an annual delay per flight of 8.47 minutes/flight**.**

- At European level, only 20 ACCs (most of them located at the edges of the European airspace) are still expected to have an operationally acceptable performance:
- 6 ACCs will record an en-route annual delay per flight of up to 1 minute/flight,
- 4 ACCs will record an en-route annual delay per flight between 1-2 minutes/flight,
- 7 ACCs will record an en-route annual delay per flight between 2-3 minutes/flight,
- 21 ACCs will record an en-route annual delay per flight between 3-4 minutes/flight and
- 7 ACCs will record an en-route annual delay per flight between 4-5 minutes/flight.

The significant delay impact is also expected to have consequences on the flight efficiency. The evaluation of such consequences was estimated on the basis of the actual route extension during a high delay day in the network with the lowest delay day in the network. Such a difference is estimated to be approximately 7 NM/flight.

C.4.2 Results from Run 1 and 2

Flight Efficiency

The annual flight efficiency benefits are expected to generate a reduction of the routes flown by approximately 18NM per flight when comparing between the current airspace structures and a full FRA cross-border implementation scenario. This benefit is applicable to both Run 1 and Run 2.

FE Benefits					
Total impacted flights	Length (NM)	Time (min)	Fuel (kg)	CO2 (kg)	NOx (kg)
26175	-471104,530	-78514,556	-3106624,730	-9816940,886	-40330,361

Table 8. Flight efficiency benefits for one-day simulation in 2035

Capacity

Figure 44 below indicate the evolution of the air traffic controller workload in a comparative manner, between the AS-IS (Current), Run 1 (Scen. 1) and Run 2 (Scen. 2).

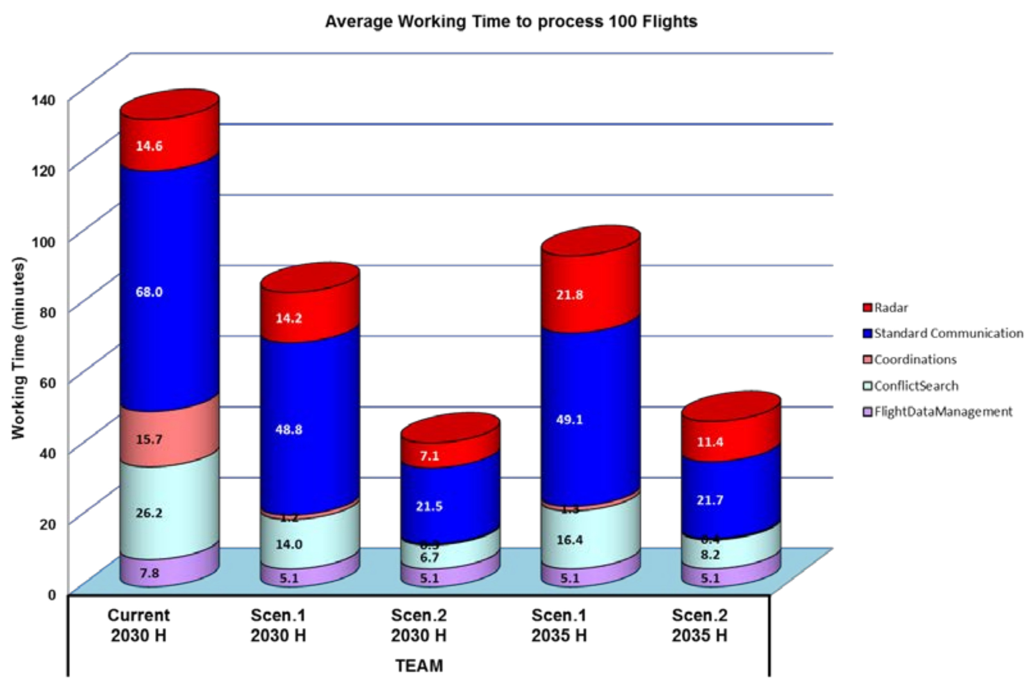

Figure 44. Average sector time to process 100 flights[89]

[89] Source: Eurocontrol/Network Manager, 2018

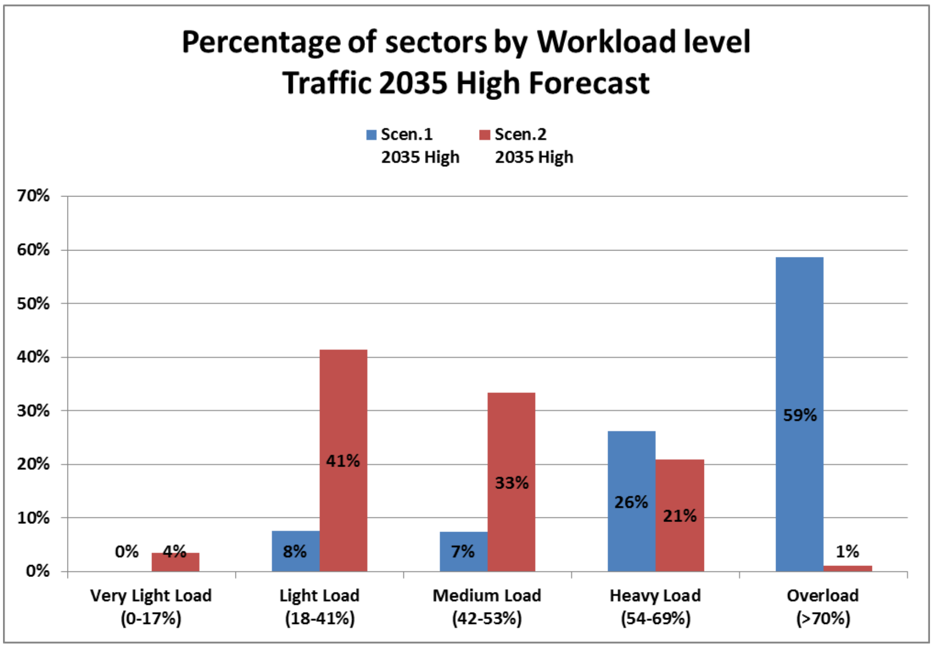

Figure 45. Workload level in 2035 for Run 1 and Run 2[90]

As the controller is able to manage more flights, there is an increase in the maximum capacity of sectors as shown in Figure 46.

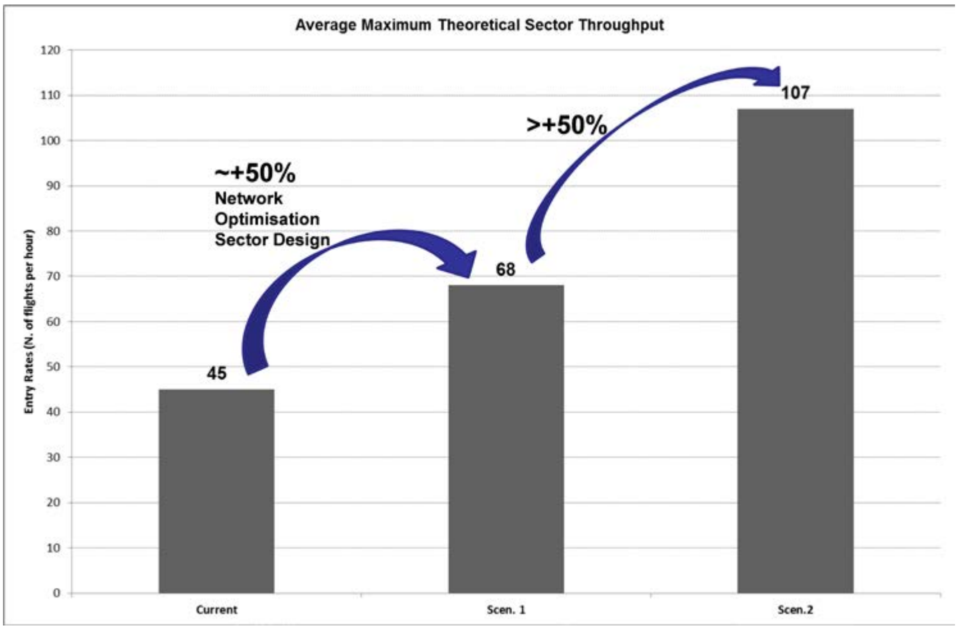

Figure 46. Average maximum theoretical sector throughput[91]

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[90] Source: Eurocontrol/Network Manager, 2018
[91] Source: Eurocontrol/Network Manager, 2018

Results on predicted delays

Figure 47 summarises the results on the predicted delays for the 3 simulations along with the number of flights per year.

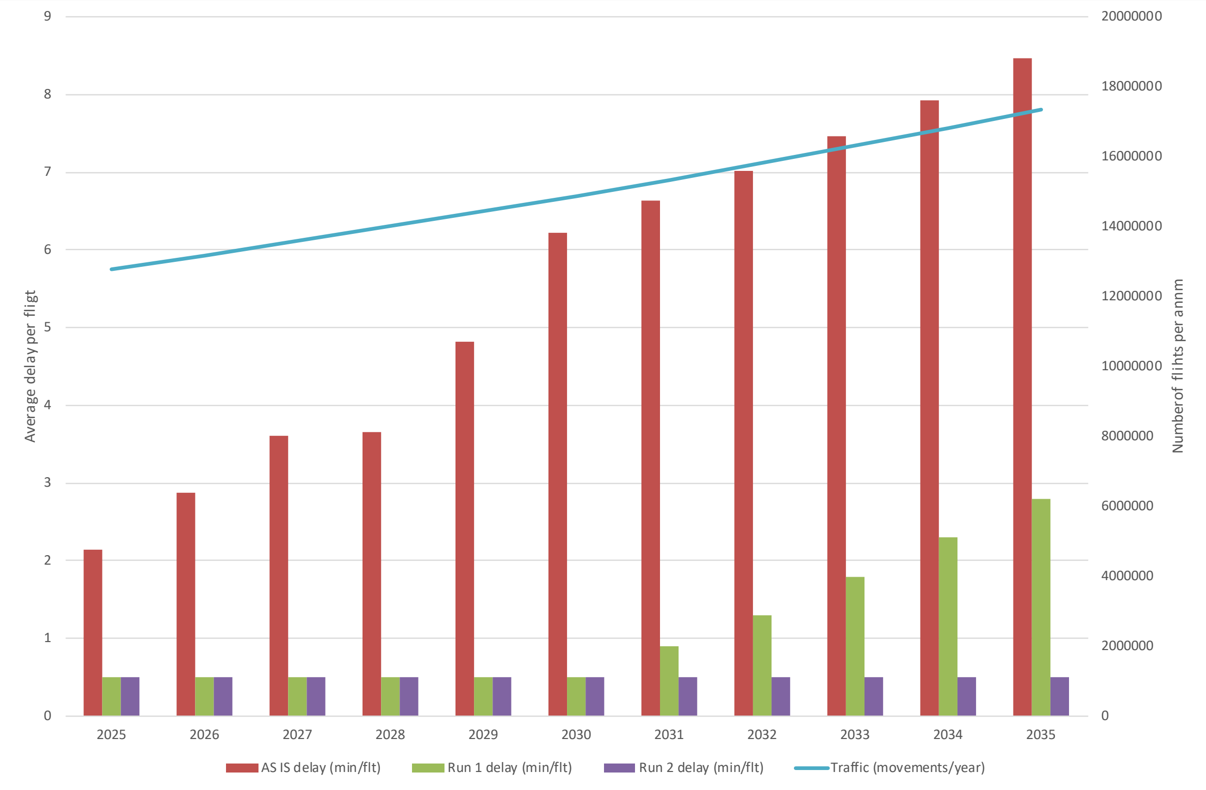

Figure 47: Simulation results: predicted delays[92]

The key results are:

a) AS-IS simulation demonstrates that the current plans are insufficient to cope with the high traffic growth scenario.
b) Run 1 simulations demonstrate that a combination of airspace design and operational harmonisation and full implementation of the PCP could provide sufficient capacity until 2030.
c) Run 2 simulations demonstrate that deployment of additional SESAR solutions could provide sufficient capacity until at least 2035.

[92] Source: Eurocontrol/Network Manager, 2018

C.5 Safety considerations

The top priority during the Airspace Architecture Study was to ensure that the solutions proposed will maintain or improve the level of safety within the European ATM network. In the context of the design of the optimised airspace organisation, the methodology used (see Annex C.3) has embedded a number of safety layers, addressing ATC workload, which are briefly described below:

- Consideration of traffic volume, density and complexity
- Reduction of the number of conflicts
- Nature of traffic
- Reduction of ATC workload
- Full coherency of all the airspace structure's elements, including the way it is used, specifically, the fixed ATS route network, Free Route Airspace, Terminal Airspace, other airspace structures such as segregated airspace, ATC sectorisation and sector configurations and the associated modus operandi;
- Flexibility to respond to varying traffic demand and to temporary changes in traffic flows;
- Operational and procedural continuity across national borders
- Optimum utilisation of the airspace and balanced load on the sectors
- Based on operational requirements rather than national boundaries
- Promote overall system flexibility (combining/splitting of sectors as needed)
- Establishing airspace structures boundaries in areas of week interaction where there are fewer conflicting flows and less evolving traffic.

In the context of the evaluation of the operational performance benefits of the solutions proposed, the methodology used was the CAPAN methodology that is regularly applied by EUROCONTROL Network Manager with a large number of ANSPs to perform simulations to estimate sector capacity, evaluate new airspace organisations and analyse ATC operations with the aim provide possible solutions to improve ATC Operations, reduce ATC workload and increase airspace capacity. The methodology has embedded in itself a number of conservative safety layers:

- It is based on the evaluation of the ATC workload;
- Several simulations runs are used where the entry times of the flights and the aircraft performances are made to vary, so as to create different situations in the ATC Sectors analysed. This reduces the possibility that the traffic sample creates a too complex or a not enough complex situation.
- In the case sectors are not sufficiently loaded, flights can be cloned in a proportional way so as to create a traffic load sufficient enough as to calculate workload and sector capacities.
- The utilisation of a 70% workload threshold that corresponds to 42 minutes measured working time in one hour, leaving 18 minutes time available for other tasks not defined within the model and also for general recuperation.
- Utilisation of an unregulated demand to ensure the most complex traffic situation
- The utilisation of busiest/most constrained scenarios
- Artificial traffic bunching
- 20 (or more) Iterations of traffic sample
- Varying the flight's entry time
- Varying the aircraft performances
- Workload tasks for Conflict Resolution using the most demanding ATC interventions
- Detection and solving of conflicts and records the ATC tasks generated by the traffic demand on the sector

Annex D Detailed description of the target service architecture

D.1 Purpose

This annex describes the proposed target architecture:

- Section D.2 provides in introduction to service orientation
- Section D.3 describes the proposed target architecture
- Section D.4 providers further details of the components of the architecture

D.2 An introduction to service orientation

The general trend in many domains is a shift from a product-based economy (exchange of assets) to a service-oriented economy reducing the operating, administrative and financial risks of businesses, and creating an environment that supports innovation. From an Airspace User perspective, at International Civil Aviation Organisation (ICAO) level many services in support of Air Traffic Management are defined in the Global ATM Operational Concept (GATMOC), including for example Air Traffic Services and Search and Rescue services.

In SESAR's European ATM architecture (EATMA), these ICAO services are further broken down by defining a logical architecture that is increasingly incorporating service-oriented architecture principles. Ongoing work in this respect relates for example to the development of so-called common services that could be used between ATM organisations. The ATM industry remains for the most part product-based, with each Air Navigation Service Provider (ANSP) owning all the assets that are required to deliver air navigation services. Underlying data services in support of providing the high level ICAO services in the current deployment architecture are not visible outside the boundaries of an ANSP, in particular as they are often embedded in legacy systems.

In order to appreciate the benefits of a service-orientated architecture, a number of terms need to be understood. The remainder of this section provides definitions for these terms.

Aviation secured high bandwidth, low latency networks

The ever-increasing network bandwidth, increasing reliability and lowering latency, in particular for ground-based networks, enables re-architecting that was not possible before. Ten years ago, Amazon concluded that every 100ms of latency cost them 1% in sales. Another study revealed that a broker could lose as much as $4 million in revenues per millisecond if its electronic trading platform was only 5ms behind the competition. Since then, low latency / high reliability requirements have grown to become critical elements of business success in many domains. As a result, networks are now able to provide secured high bandwidth, low latency networks for critical applications not only in trading and finance, but also for safety critical domains like aviation. Safety criticality from an operational perspective translates to time-criticality and cyber-security from a technical perspective.

Vertical and geographical de-coupling of services

Service orientation is about separation of concerns by de-coupling the functions of different layers to the greatest extent possible. It enables splitting tightly integrated legacy systems into independently operated services with minimised interfaces between them. End-user services consume integration services, integration services consume elementary services. This is called vertical decoupling into different layers.

With the support of secured high bandwidth, low latency networks, all functions that are not directly linked to a geographically-fixed entity, can now be run from anywhere. A consumer service can run in one place, and the provider service in another. This is called geographic decoupling.

Virtualisation

If services are provided purely using digital means, and their implementation is decoupled from the physical hardware on which they are executed, the virtualisation of services (i.e., moving part or all functionality into a private or public cloud environment) can be enabled.

Horizontal re-integration of services

The concept of services enables similar organisations to consume a service from one or more providers, giving them the same capability, they would normally have provided themselves, but at a scalable operating cost rather than a rigid and often inefficient capital investment.

Horizontal re-integration of services through consolidation of services within the same layer occurs when two or more service providers agree to offload a service of the same layer to a common provider of that service. The provider of the offloaded common service could be a new organisation or could be part of one of the existing organisations. It puts the focus on consumer's expectations and pay-to-use rather than pay-to-own.

Interoperability

Considering that in the global aviation context, no single service implementation of whatever nature will cover the whole world and that there will always be operations that require the successive services of different service providers, there is also an interoperability requirement[93] on various ATM services within the same layer. As an example, while it may be possible to contract internet services as a consumer from any given provider using a standard interface, there is also a need for all internet service providers to be interoperable with and connected to several other internet service providers, so that any two end-users can be connected with each other. Common service interfaces for the consumers normally need to be standardised in order to facilitate access to the market by new entrants. The notion of System-Wide Information Management (SWIM[94]) is now globally adopted and serves as the reference for achieving such interoperability based on agreed open standards in the ATM domain. In a limited interoperable environment, parties may also offer new broker type services that disconnect the consumer(s) from a possible range of different underlying service implementations and that take care of selecting the best possible service for a given transaction.

Resilience

Resilience is the ability to cope with disruption in an effective way and to minimise its impact on the quantity and quality of service provided. Current practice is generally to depend on a combination of local redundancy mechanisms to avoid single points of failure and on degraded modes of operation to ensure continuity of service but at lower capacity and possibly with lower efficiency. Interoperable

[93] A distinction is made between technical interoperability as explained in this technical annex, versus the way interoperability is implemented from a regulatory perspective. From a regulatory perspective interoperability is achieved by making the systems and constituents compliant with the essential requirements

[94] Manual on System Wide Information Management (SWIM) Concept, Doc 10039 AN/511 (Available at: https://www.icao.int/airnavigation/IMP/Documents/SWIM%20Concept%20V2%20Draft%20with%20DISCLAIMER.pdf)

services within the same layer allow for an increase in resilience without necessarily the need to fall-back to degraded modes.

Scalability

A service is said to be scalable if an increase of resources in a system, results in an increased performance in a manner that is proportional to resources added. Increasing performance in general means serving more units of work.

D.3 The ATM logical service architecture

Traditionally Air Navigation Services are organised at national level using monolithic systems with tight coupling between air traffic services, flight data processing and data integration exist. Internal interfaces are often either national ANSP tailored or proprietary interfaces from the supply industry that provided the monolithic system. Figure 48 illustrates the current ANSP architecture.

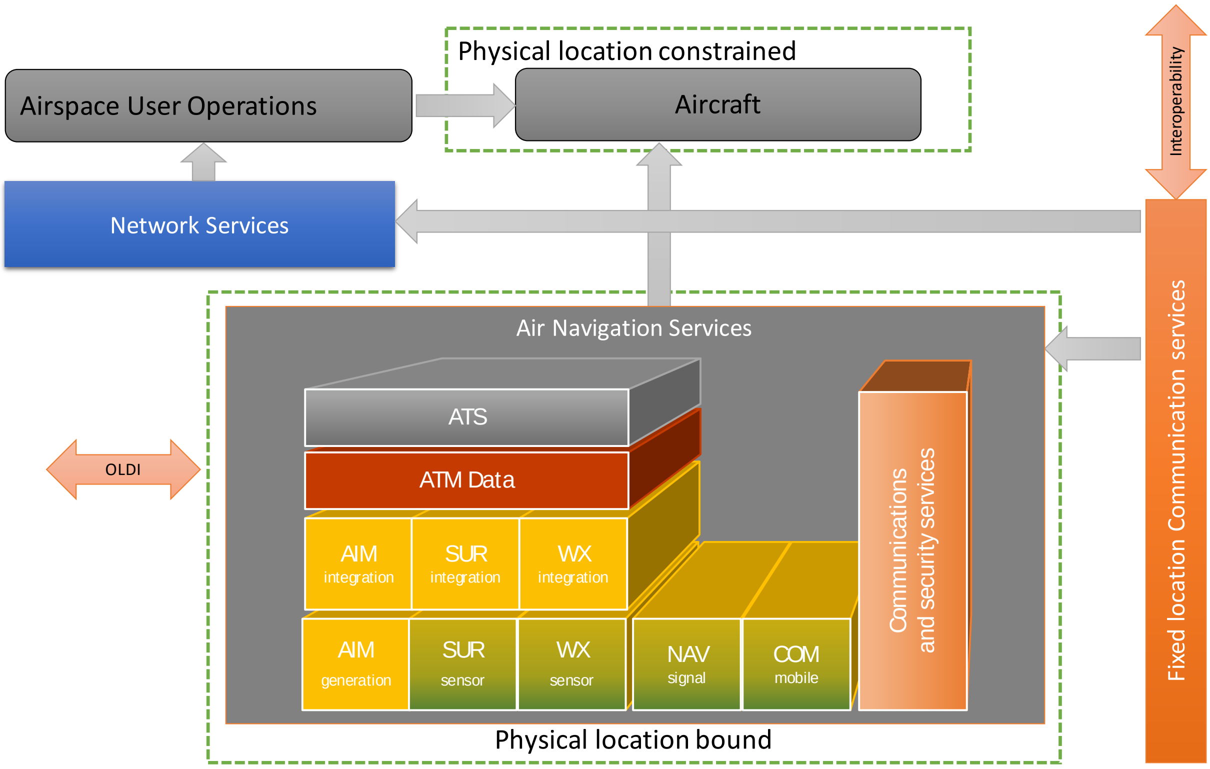

Figure 48. Traditional monolithic set-up, with all services integrally provided by one ANSP[95]

[95] Source: SESAR JU, 2018

Figure 49 illustrates the proposed high-level logical architecture designed to enable vertical decoupling of services. The purpose being to increase the resilience of the services at each layer, and introduce scalability at each layer.

- Example 1: Dynamic capacity management would allow adapting the air traffic service (ATS) capacity at short notice to ensure the quality of service (increase delays) and efficiency of service delivery, even when the demand is different from what was initially planned. In practice this could be done by re-allocating unused capacity of the various services from one ANSP, with less traffic than foreseen, to assist in handling traffic in the airspace of another ANSP where actual traffic is higher than forecasted (or where capacity to deliver the service is reduced due to e.g. technical issues). This would make the Air Traffic Services more resilient to demand variations.
- Example 2: Resilience of ATM data services would be increased in case of a technical failure of (one of the components of) a flight data processing system, by being able to instantaneously replacing it with another which integrity is still intact.

The concept is not to conclude on specific implementation choices, but merely to provide a flexible architecture that allows stakeholders to implement their desired different implementation options. The logical architecture is the starting point for identifying the virtual infrastructure required for the vertical and geographical de-coupling of services, resulting in the re-integration of services into horizontal consolidation, increasing flexibility, scalability and resilience.

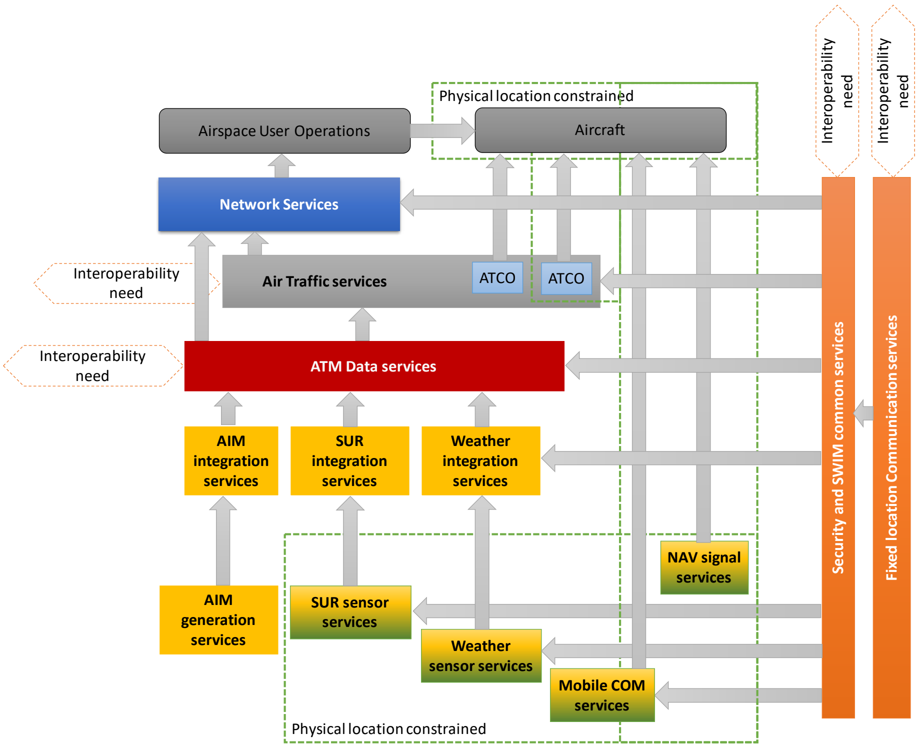

Figure 49. Proposed service-oriented architecture depicting service (not information exchange) flows[96]

[96] Source: SEAR JU, 2018

In a service-oriented business context, providers and consumers are linked through service level agreements (SLAs) to agree contractually on quality of service aspects like reliability, availability, security. An inherent element of every SLA between service provider and service consumer is to define the service availability, including the availability of any possible degraded levels of service. For organising the delivery of the service, the provider will normally put a service delivery management capability in place that will ensure that the service is available as agreed, despite any possible disruptions caused by an unavailability of internal resources, or by problems in using subsidiary services from other providers.

When aiming to decouple services vertically and geographically, an important consideration to start with is that some services of the architecture have a fixed relationship with a geographical location. These are in particular the communication navigation and surveillance (CNS) systems that send and/or receive radio signals, as well as meteorological sensors. Also, the aircraft operated by the airspace users have a given physical location relative to the CNS systems at any moment in time.

All the other services in this logical architecture can be defined such that their geographical area of coverage/responsibility is either irrelevant, dynamically configurable or fixed.

Figure 50 indicates which services are geographically independent in the proposed logical service architecture, and which are geo-fixed. The services can be further detailed into functions. These functions, and the options for deployment architecture, are further elaborated in the next sections.

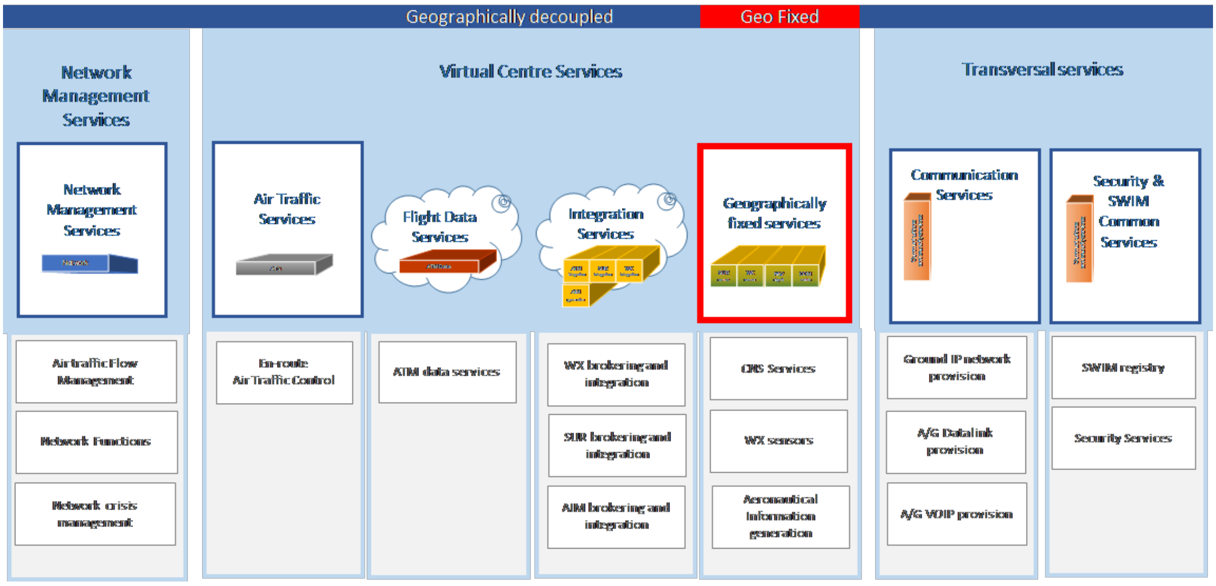

Figure 50. Proposed services and their functions

Once implemented the proposed target architecture will enable a fundamental transformation of service provision. Figure 51 illustrates the service provision roles within traditional monolithic architecture; Figure 52 illustrates the flexibility of the proposed target architecture to enable vertical de-coupling and horizontal re-integration of services.

For example, with the current organisation of air navigation services (ANS) provision service resilience is largely dependent on the resources of individual ANSPs; vertically de-coupling of services allows service resilience to be managed between ANSPs and even at network level.

Example of a traditional monolithic architecture

Traditionally both the ANSP's area of responsibility and their geographical deployment correspond with state boundaries. Using a fictitious continent, the diagrams below illustrate the organisation of ANS largely along state lines:

Organisation A provides Network Management services for all ANSPs.
Organisations B to F are ANSPs operating between 1 and 3 ACCs at State level
All 10 ACCs require full local implementation of all services.

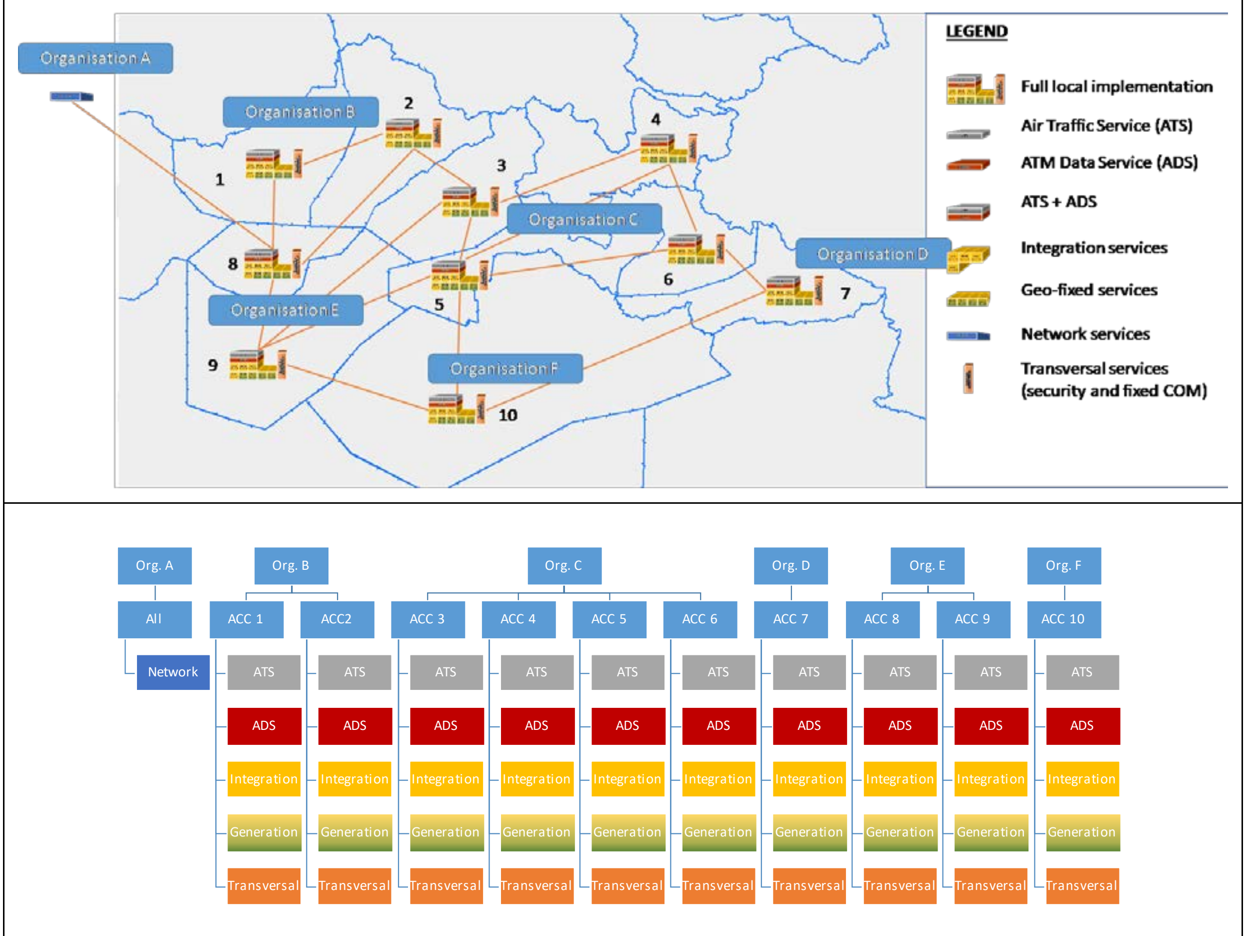

Figure 51. Service provision based on monolithic architecture[97]

[97] Source: SESAR JU, 2018

Illustrative example of a geographically decoupled service architecture

For the same fictitious continent, the following diagrams illustrate a potential organisation of ANS service provision based on the proposed target architecture:

- Organisation A provides network management services for all ACCs
- At the locations of ACC1 to ACC10 geo-fixed services are provided
- Organisation N provides integration services to all data services, except for organisation F and K that have their own integration services. They integrate information coming from the 10 geo-fixed locations. Integration services are location independent.
- Organisations L and M both provide ATM data services. Both consume integration services from organisation N, consume the transversal services from either organisation G or H, and connect to organisation A for network management services.
- Organisations B and C provide Air Traffic Service (ATS), based on ATM Data Services (ADS) from either organisation L or M. Organisation B provides ATS for ACC1 and ACC2, organisation C provides ATS for ACC3, ACC4, ACC5 and ACC6.
- Organisation D provides ATS based on a full local implementation, but can also provide ATS based on the ADS services from either organisation L or M.
- Organisations G and H provide transversal services (security and communication)

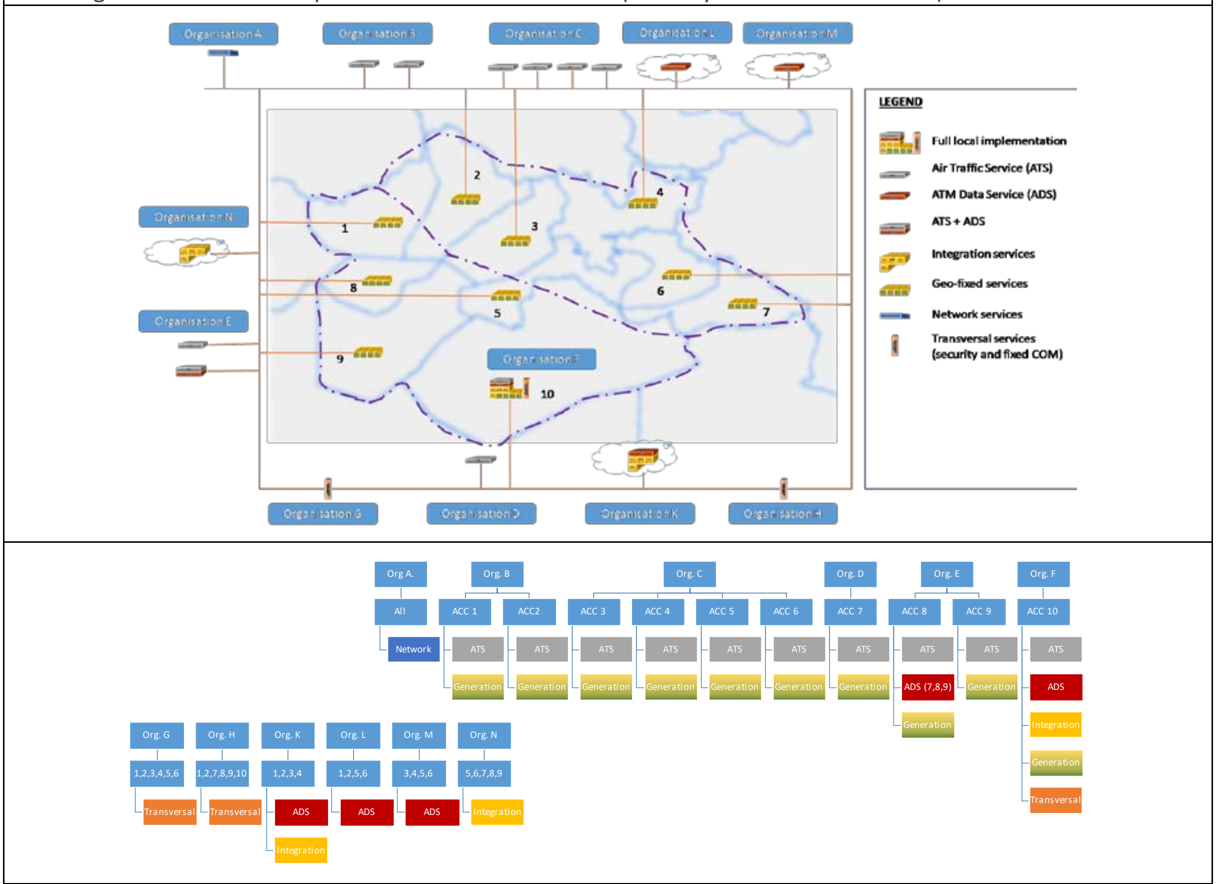

Figure 52. Service provisions based on a service-oriented architecture[98]

[98] Source: SESAR JU, 2018

In the new architecture, Virtual Centres will provide Air Traffic Services to one or more ACCs that may or may not be adjacent to each other. As shown in Figure 53, a Virtual Centre may consist of multiple organisations, each specialised in a different type of service. The various services that build up a Virtual centre are:

- Air Traffic Services (consuming ATM data services)
- ATM Data Services (consuming integration services)
- Integration Services (integrating information from different regions of geo-fixed services)
- Geo-fixed services (in support of CNS)
- Transversal services (security and communications)

Note that any organisation could provide services to any number of Virtual Centres. For example, in Figure 53, organisation L provides ATM Data Services to both Virtual Centre Q and Virtual Centre P.

Network management services are provided at a European level to ensure the integrity of the European network, in collaboration with all Virtual Centres.

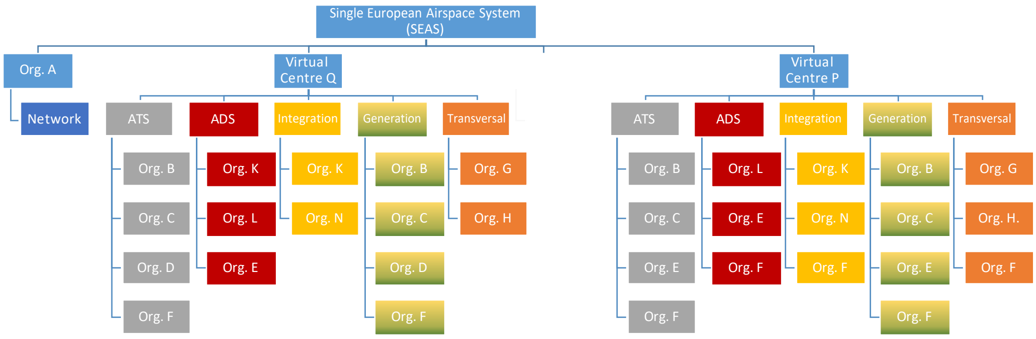

Figure 53. Organisational decomposition using service orientation[99]

The new architecture does not need to be implemented as a big bang. Because of its services nature, service deployment can be done step by step whenever for any subset of ANSPs a layer is sufficiently harmonised to be vertically decoupled and consequently services of that layer can be horizontally re-integrated. Many combinations may co-exist at the same time, as illustrated in Figure 52, allowing for a transition that respects earlier investments in non-service-oriented legacy systems, on a case-by-case basis.

[99] Source: SESAR JU, 2018

D.4 Architecture Components

D.4.1 Scope

This section provides a more detailed description of the each of the architectural components of the proposed service-oriented architecture.

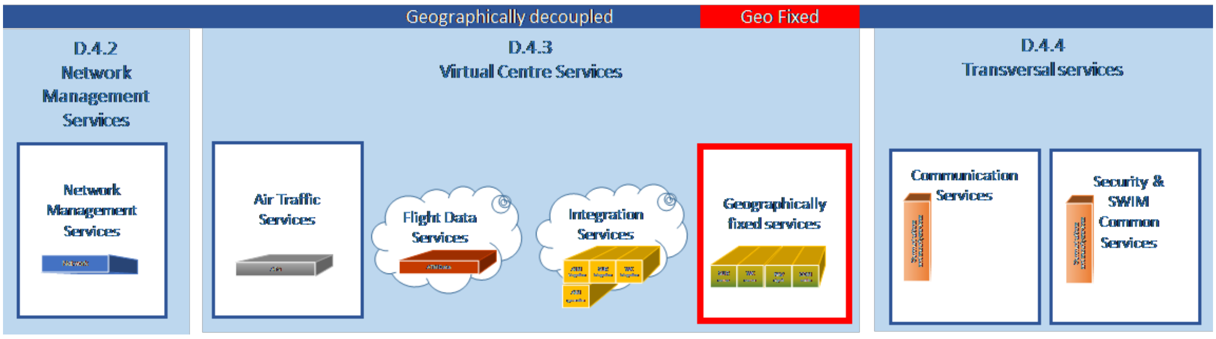

Figure 54. Architecture components[100]

D.4.2 Network management services

Irrespective of a monolithic or a service-oriented ATM architecture, network management services are required at a European level to ensure the integrity of the European network.

The current network functions and Network Manager tasks[101] will need to continue and may in the future be augmented by additional services.

D.4.3 Virtual Centres

In SESAR1, research on the notion of Virtual Centres was initiated. In SESAR 2020, this matured by adopting the definition of a virtual centre as “one or more air traffic service units (ATSU) using data services provided by ATM data service providers (ADSP).

The concept provides, at least, geographical decoupling between ADSP (s) and some ATSU (s), through service interfaces defined in Service Level Agreements. One ATSU may use data services from multiple ADSPs, just as an ADSP may serve multiple ATSUs. It enables state border independent Air Traffic Control (ATC) service provisions”.

[100] Source: SESAR JU, 2018

[101] Commission Regulation (EU) No 677/2011 of 7 July 2011 lays down detailed rules for the implementation of air traffic management (ATM) network functions and amending Regulation (EU) No 691/2010. On the 27th of November 2018, the Single Sky Committee voted positive on the adoption of a new Commission Implementing Regulation laying down detailed rules for the implementation of air traffic management (ATM) network functions and repealing Commission Regulation (EU) No 677/2011.

Therefore, the proposed target architecture, the definition of the Virtual Centre is extended to encompass:

a) Air traffic services

b) ATM data services

c) Integration services

d) Geographically fixed services

The main principles are illustrated in Figure 55.

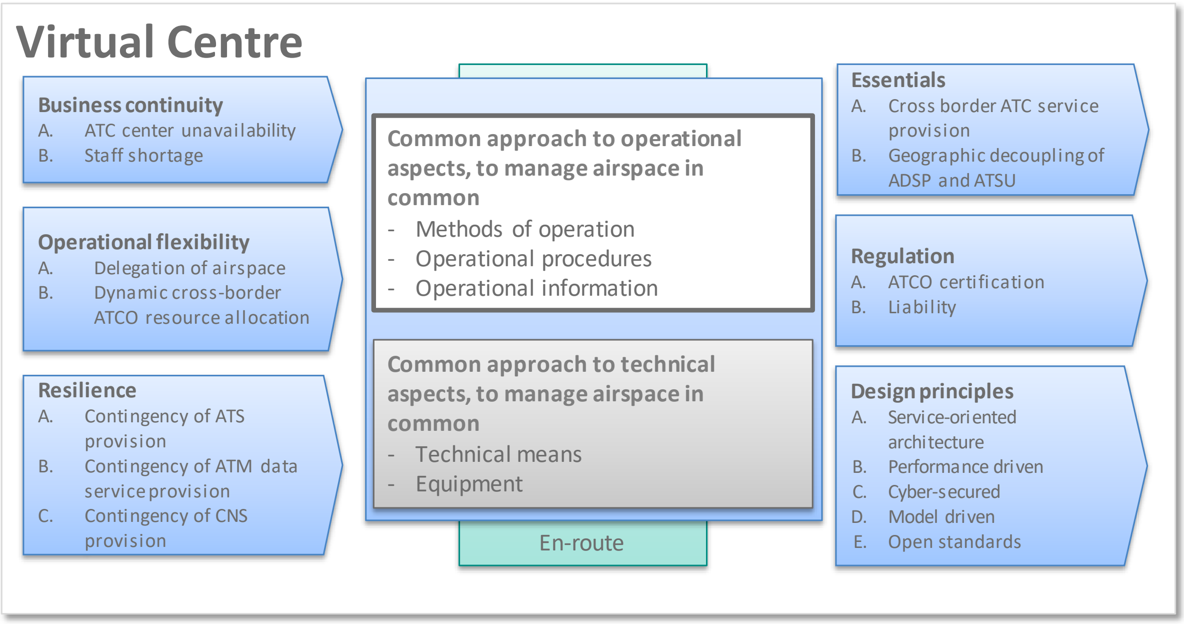

Figure 55. The Virtual Centre concept[102]

D.4.4 Air traffic services

ATS services is the provision of separation (and sequencing) of aircraft within a given airspace. Air traffic controllers provide those services using a controller working position and associated automation tools.

In current operations, each executive controller is fully in charge of all the flights in an ATC sector. An alternative approach for increasing productivity consists on better balancing workload amongst controllers by rethinking traditional sectorisation concepts. Solutions that support dynamic sectorisation enable ANSPs to better match sectorisation to demand to maximise the capacity that can be offered with the staff that is on duty at a given moment in time.

The new architecture would enable ANSPs to take this approach a step further, by allowing ANSPs to pool resources by allocating a specific sector to the ACC that has enough controllers to staff it.

[102] Source: SESAR JU, 2018

This requires a common approach on the operational and technical aspects that are required to manage airspace in common. This regards methods of operation, operational information and operational procedures, as well as technical means and equipment. However, its implementation would still be limited because controllers can only safely work in a limited number of sectors.

SESAR's research is working on overcoming this limitation by expanding the number of sectors that a controller can be validated for by providing automation support so that controllers' knowledge of the local area can be complemented by the system. The most advanced of such concepts is referred to as tools-based controller validation, which aims at having controllers validated to work with a specific system, regardless of the geographical area where the service is delivered.

D.4.5 ATM data services

In the SESAR virtual centre solution, the core of the ANS flight and other information management capabilities and further automated control functions are considered candidate to be defined as what is called an ATM Data Service. Whereas the geographical coverage of these capabilities is currently coinciding with the area of responsibility of each ANSP, decoupling these services from the actual operational service provision, would allow each service to support any arbitrary geographical scope.

The ATM data services perform functions like flight correlation, trajectory prediction, conflict detection and conflict resolution, safety nets, arrival management planning. They are consuming underlying integration services for weather, surveillance and aeronautical information.

The high level of technical interoperability that allows any ATSU to connect to different ATM Data Service providers (ADSPs), requires standardised service-oriented interfaces between ATSU and ADSP. Their design is performance and model driven, cyber-secured and building on open standards.

D.4.6 Integration services

The possible integration services for Aeronautical Information Management (AIM), Surveillance (SUR) and Weather (WX) would combine the geographically constrained scope of the underlying provision services in a service with a broader geographical coverage and that would hide any service specificities of the underlying providers. They can also broker between different underlying services with different qualities, e.g. satellite Automatic Dependent Surveillance-Broadcast (ADS-B) or radar based surveillance services. A perfect competition model would appear quite feasible for this kind of service, certainly if considered at a global scale.

D.4.7 Geographically-fixed services

Several services of the architecture have a fixed relationship with a geographical location.

- There are air-ground communication services with physical coverage of the location of the vehicle.
- The necessary navigation signal services cover the location of the vehicle, based on its physical location.
- There are surveillance sensors with physical coverage of the location of the vehicle.
- There are weather sensors in the area of that location that can feed weather forecasting services.

Terrestrial Air/Ground VOIP to replace existing VHF radios

A pre-requisite for geographically independent ATC service is the replacement of terrestrial analogue R/T radio transmission between ATC and aircraft to terrestrial digital air-ground communications via Voice over IP (VOIP).

Moving to VoIP allows for geographic decoupling, making the remote provision of ATC service much more flexible: VoIP can be re-routed to the Aircraft via aviation secured high bandwidth, low latency networks to the VoIP antenna closest to the aircraft.

For the flight-centric solution, when remaining with analog R/T, communication has to be supported by wide area communication technology. Current ground communication infrastructure would need to be modified in order to allow flexible allocation of frequencies to the assigned controller and aircraft. When transitioning to A/G VoIP, this geographical limitation on the flight centric solution no longer exists.

Advanced Air/ground datalink

Concepts based on air/ground synchronisation which include more system-to-system exchange of data that do not require the intervention of either pilots or controllers, will incorporate a flexibility for updates that has been unknown to date in the avionics world.

A continuous and accurate synchronisation between aircraft and air traffic control, as is paramount in the vision of Trajectory-Based Operations (TBO), requires the introduction of new high reliable, low latency technology for air-ground communications covering both voice and data.

The SESAR programme is developing this future communication infrastructure (FCI) by combining the future terrestrial datalink, also referred to as LDACs; the future Satellite Communications Data link, and the future network technology supporting the multi-link concept.

Research into advanced use of data link will be looking at leveraging the potential of the new data link over the L-band (LDACS) under development in Wave 1 in combination of the air-ground synchronisation though the ATNB2 standard (SESAR 2020 Wave 2).

D.4.8 Transversal services

Transversal services are essential functions required by all other services. They consist of:

- Ground-ground communication services; and
- Security and SWIM common services.

Ground-ground communication

Ground-ground communication services can be organised in various ways, recognising that ATM ground-ground communication is just a small market compared to the total communications market in Europe. While the performance requirements (e.g. availability, latency) of ATM may be high compared to some other industry segments, there are no functional differences in the services needed compared to other users. Providers of these services will already work across many different industry markets. All users of these ground-ground communication services can choose to work with one or multiple providers (e.g. to spread the requirement for service availability over multiple providers).

Security and SWIM common services

The SWIM common services as defined in the PCP are built up of the SWIM registry as the yellow pages for common service management and the Public Key Infrastructure for common identity management.

Beside the SWIM Public Key Infrastructure (PKI), the transversal security services include security risk assessment sharing, threat intelligence collection and distribution, vulnerability information sharing and last but not least cyber-attack response coordination.

The transversal services need to be interoperable between different implementations/providers. How they are implemented and from where they are operated is irrelevant, as they have no relationship with geographical location.

D.5 Cyber security

The current ATM system is a patchwork of bespoke systems and networks connected by a bewildering array of different interfaces, often utilising national and proprietary standards. It is clear that the proposed target architecture of the European ATM system will rely on an increase in interconnected systems that utilise modern technologies and interoperability to deliver operational improvements through a shared view of all aeronautical information. Two key concerns that threaten these benefits are underlined:

- Increased interconnectivity and integration both in terms of interactions between actors (ANSPs, airlines, airports, aircraft) and CNS systems expand the attack surface and create new vulnerabilities, for example through third-party access to networks and systems.
- Interoperability implies an increased use of commercial-off-the-shelf (COTS) components and without careful planning a corresponding loss of diversity. This increases the likelihood of introducing common vulnerabilities into the system.

In particular, the principles of system-wide information management (SWIM) on which the service interfaces are built, presents opportunities to establish the necessary IT service management principles and cybersecurity architecture at an early stage of development, before the costs of retrofitting access control, intrusion detection and forensics become prohibitive.

For ATM, a number of guiding principles should be defined for the organisational and technical measures that are needed to encourage cyber resilience. The proposed target architecture consists of solutions that are provided with security requirements that stem from an initial security risk assessment during SESAR’s R&D phase. On top, the architecture itself contributes through it’s flexibility and redundancy to the overall cyber resilience.

In general, and beyond the scope of this study, cyber security practices in ATM will need to be adapted to comply with the relevant European regulatory framework that is not always aviation specific: GDPR, NIS Directive, EC 373/2017. There is a need to define and agree acceptable means of compliance, guidance, manual, standard and training requirements. Though needed, the current State-based approach is not sufficient, sustainable in a domain like aviation where by definition activities are cross-border and with such a level of interoperable interconnections and interfaces. For example, it is essential to address the requirements for cross-border collaboration in the context of cyber security, as well as sharing of information about cyber threats and vulnerabilities.

The European Strategic Coordination Platform for Cybersecurity in Aviation, has been established in 2018, as joint effort of all European Aviation stakeholders, to address these new cyber challenges.

D.6 Illustrating the AS-IS and TO-BE architectures

While architectural descriptions generally separate different elements in separate views, the following figures are provided to give a simple integrated overview of both the AS-IS and TO-BE architecture.

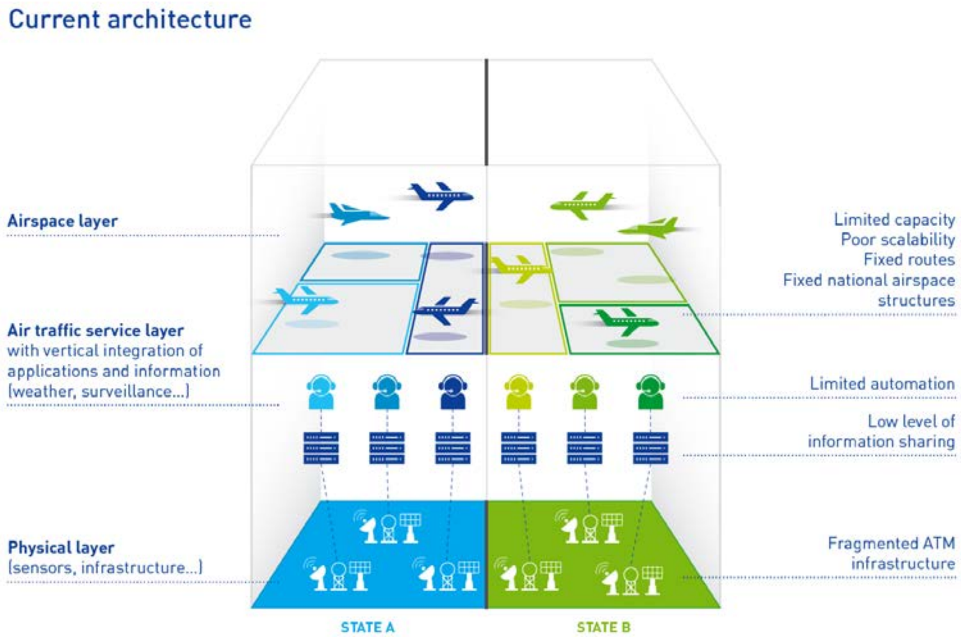

Figure 56: Illustrative overview of AS-IS architecture

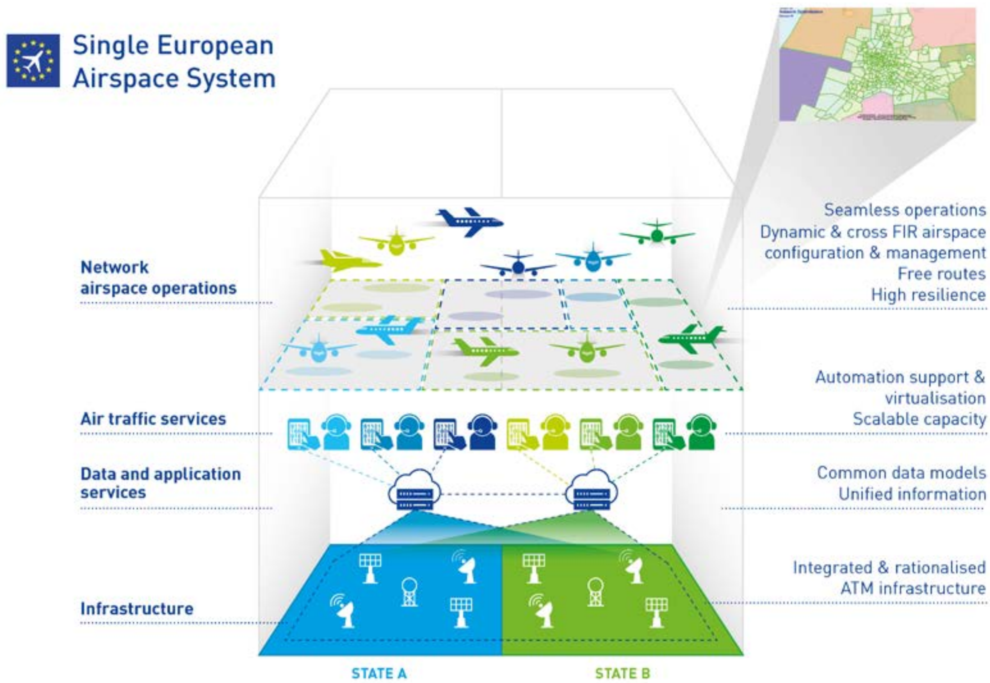

Figure 57: Illustrative overview of TO-BE architecture

Annex E SESAR solutions underpinning the study

E.1 Purpose

This annex provides details of SESAR solutions considered for deployment in this report. Only the solutions considered being essential to support the proposed recommendations are included. They are mapped against the focus areas described Section 4 noting that several solutions contribute to both focus areas.

It should be noted that many other SESAR solutions, not listed here, contribute to improving the overall ATM performance and could bring further benefits when deployed in line with the European ATM Master Plan.

An analysis was also performed to evaluate the potential gaps between the recommendations of this report and the SESAR solutions (already delivered or in the research pipeline) using the assumption that the solutions contained in the Pilot Common Project (PCP) form part of the current baseline. The analysis concluded that implementation of the proposed target architecture is fully covered by a selection of thirty-nine SESAR solutions.

In terms of maturity, 95% of the required solutions are either ready for deployment (SESAR1) or expected to be ready at the end of S2020 wave 2. Only three candidate wave 2 solutions (solution number 56, solution 73 and solution 88) would require further validation beyond wave 2.

The analysis assumed that all wave 2 candidate solutions will be successfully rewarded. Given the uncertainty of the final outcome of SESAR 2020 Wave 2 call, the gap analysis should be revised once the final wave 2 programme is known.

E.2 Focus area 1: Airspace and capacity

E.2.1 Optimised Airspace organisation

The creation of a seamless cross-FIR FRA for the whole ECAC region would allow airspace users to fly their preferred route across the entire ECAC airspace (subject to airspace availability, military airspace reservations, and ATM approval) without intermediate entry and/or exit point inside the ECAC airspace. In other words, flights should follow a direct trajectory from entry into the ECAC airspace to exit without required intermediate entry/exit points along the way (which is currently the case today even between different FRA areas).

Advanced FUA (A-FUA), as included in the Pilot Common Project, enables a demand-driven collaborative approach where the civil and military state their needs and the ATM system coordinate to provide suitable and balanced solutions.

Optimal flow-centric redesign of sectors would maximise capacity with minimal changes to controller workload. However, this requires removing some constraints currently imposed by national/FAB/FIR boundaries. The proposal is to progressively apply the airspace design principles already defined in the Network Functions Implementing Rule to ensure the gradual transformation of the airspace, while building on existing best practices.

Solutions listed here support the recommendations of the AAS in the areas of ECAC-wide Free Route Airspace, Flexible Use of Airspace and Optimised cross-FIR sectorisation.

ID	Title	Description	Delivered in
#32	Free route through the use of direct routing	Direct routing is established within direct routing airspace with the aim of providing airspace users additional flight planning route options on a larger scale across FIRs such that overall planned leg distances are reduced in comparison with the fixed route network and are fully optimised. Direct Routing Airspace defined laterally and vertically with a set of entry/exit conditions where published direct routings are available. A Direct Routing is a published segment of a great circle between 2 published waypoints.	SESAR 1 (PCP)
#66	Automated support for dynamic sectorisation	Automated support for Dynamic Sectorisation provides supporting tools to areas with high traffic density to evaluate the most suitable Air Traffic Control airspace configuration (sectors). Dynamic Capacity Management allows adapting the capacity to traffic load by grouping and de-grouping sectors and managing the staff resources accordingly. Unused latent capacity can occur at all Flow Management Positions (FMP) during peak traffic times. Current tools facilitate the detection of overload but do not offer better options to deal with it.	SESAR 1 (PCP)
PJ.06-01	Optimised traffic management to enable free routing in high and very high complexity environments.	Optimised traffic management to enable Free Routing in high and very high complexity environments sees airspace users being able to plan flight trajectories without reference to a fixed route network or published directs within high and very high-complexity environments so they can optimise their associated flights in line with their individual operator business needs or military requirements. The solution provides a description of high and very high complexity cross-border Free Routing environment in upper airspace (at the 2022 timeframe - as per PCP AF#3). The scope of the solution focuses on the improvement of Aircraft-to-Aircraft Separation Provision to enable Free Routing operations in upper airspace in high and very high complexity cross-border environments (with minimum structural limits to manage airspace and demand complexity).	SESAR 2020 Wave 1

E.2.2 Operational harmonisation

The objective of operational harmonisation is to reduce operational performance variation between ACCs, by ensuring that all ACCs are operating at the performance levels of today's top 10-20 ACCs. It should also lead to a more harmonised operational concept and increased levels of inter-ACC interoperability.

Solutions listed here support the recommendations of the AAS in the area of operational harmonisation.

ID	Title	Description	Delivered in
#37	Extended flight plan	The extended flight plan is an extension of the ICAO 2012 FPL. New information encompasses: - The 4D trajectory as calculated by the FOC flight planning system in support to the generation of the operational flight plan. The 4D trajectory information in not limited to 4D points. It contains additional elements for each point of the trajectory such at speeds, and aircraft mass; - Flight specific performance data: the climbing and descending capabilities of the aircraft specific to the flight. Short term use cases for EFPL are: - Use extended flight plan information to improve the process of validation of flight plans by the Network Manager, in particular by reducing the number of flight plan rejections resulting from the low resolution of the ICAO 2012 flight plan; - Use extended flight plan information to improve traffic predictions for traffic flow/complexity management; - Use extended flight plan information to improve ATC processes (traffic prediction, detection/resolution of conflicts, AMAN operations).	SESAR 1 (PCP)

ID	Title	Description	Delivered in
#46	SWIM yellow profile	To foster interoperability within the future European ATM Network (EATMN) as envisaged by SWIM, the SESAR programme developed a series of documents covering aspects such as concepts, service descriptions, templates, governance and a series of technical resources such as models. The SWIM Technological solution provides a coherent set of specifications providing essential requirements that are applicable to the standards used in the context of SWIM deployment. These documents are seen as the key elements in steering SWIM enabled systems for ensuring the interoperability; AIRM; Semantic interoperability | ISRM: 3.1 Organisational interoperability | SWIM TAD, profiles, SWIM TI; SWIM Technical Infrastructure (SWIM TI) and architecture shall enable technical interoperability | The SWIM registry aims at improving the visibility and accessibility of ATM information and services available through SWIM. It enables service providers, consumers, and the swim governance to share a common view on SWIM. The SWIM registry provides consolidated information on services that have been implemented based on SWIM standards. Registry Technical Specification and Registry Concept of Operation documents provides information and requirements required for the implementation of SWIM registry.	SESAR 1 (PCP)

ID	Title	Description	Delivered in
#115	Extended projected profile (EPP) availability on ground	Trajectory management is a key cornerstone of the ATM system. The better the trajectory prediction is, the better the whole ATM system will be. Nowadays there are multiple trajectory predictions held and maintained by air and ground actors. They take into account different parameters (e.g. aircraft model, route/restrictions, operating preferences & weather forecast) leading to inconsistencies and different accuracy levels depending on flight phases. These inconsistencies lead to an inefficient ATM system as a whole. "EPP availability on ground" technological solution is a first step towards a full ground-air trajectory synchronisation required for the implementation of the targeted Trajectory based operations. It allows the provision to the ground systems of the aircraft view on the planned route and applicable restrictions known to the airborne system, together with the corresponding optimal planned trajectory computed on-board and speed preferences. This information is automatically downlinked from the airborne Flight Management System via ADS-C data link to the ground ATC unit which has subscribed to the needed service contract (e.g. Extended Projected Profile & Speed Schedule Profile contracts) and made available to the controllers.	SESAR 1 (PCP)
PJ.18-02b	Flight object interoperability	"The IOP activities include the definition of the IOP Solution, based on the SESAR 1 Solution #28. The IOP scope has been divided into a basic scope, sufficient to deploy IOP in the core area of Europe, and the Full scope, which provides additional IOP functionalities.”	SESAR 2020 Wave 1
PJ.18-02c	eFPL supporting SBT transition to RBT	This Technological Solution will look at the distribution of eFPL information to ATC systems, and at the possible improvements of the alignment of AUs’ and NM's trajectories especially concerning use of PTR s and Standard Instrument Departure (SID)/Standard Arrival Route (STAR) allocation.	SESAR 2020 Wave 1

ID	Title	Description	Delivered in
Candidate solution #8	Dynamic E-TMA for advanced continuous climb and descent operations and improved arrival and departure operations	The objective of this solution is to improve descent and climb profiles in busy airspace, as well as the horizontal flight efficiency of arrivals and departures, while at the same time ensuring traffic synchronisation, short-term DCB and separation. This requires a very broad scope, which includes advances in airspace design, development of ground tools, and development of ATC and airborne procedures.	SESAR 2020 Wave 2
Candidate solution #38	Enhanced integration of AU trajectory definition and network management processes	The objective of this solution is to reduce the impact of ATM planning on Airspace Users' costs of operations, by providing them a better access to ATM resource management and allowing them to better cope with ATM constraints. The solution shall improve Airspace Users flight planning and network management through improved FOC participation into the ATM network collaborative processes in the context of FF-ICE and its potential evolutions.	SESAR 2020 Wave 2
Candidate solution #44	Dynamic airspace configurations (DAC)	The objective of the solution is to improve the use of airspace capacity for both civil and military users by increasing the granularity and the flexibility in the airspace configuration and management within and across ANSPs' areas of responsibilities. This solution will address the integration of concepts and procedures to allow flexible sectorisation boundaries to be dynamically modified based on demand. This includes potential implications for ATCO licences, international boundaries and potentially IOP and A/G multi-datalink communication capabilities.	SESAR 2020 Wave 2

ID	Title	Description	Delivered in
Candidate solution #70	Collaborative control and multi sector planner (MSP) in en-route	The solution addresses the collaborative control with unplanned boundaries concept, in which the traditional requirement to coordinate traffic at all sector boundaries is waived for an area covering two or more sectors. In case it is not completed in wave 1, the solution scope covers as well the development, for the en-route environment, of the concept of operation and the required system support e.g. coordination tools for operating in a team structure where a Planner has responsibility for the airspace under the executive control of two or more independent Executive Controllers (multi-sector planner or MSP). The MSP is able to adjust the internal (executive) sector boundaries so that workload is balanced between the Executive controllers.	SESAR 2020 Wave 2
Candidate solution #93	Delegation of airspace amongst ATSUs	The objective of this solution is to explore the different possible delegation of airspace amongst ATSUs based on traffic / organisation needs (either static on fix-time transfer schedule (Day/Night) or dynamic e.g. when the traffic density is below/over certain level) or on contingency needs. The solution covers an operational thread, which aims at defining and validating the different types of delegation of airspace and a technical thread, which aims at specifying the impacts of the operational thread on the services defined in the Virtual centre concept.	SESAR 2020 Wave 2

E.2.3 Automation and productivity tools

Automation support for controllers is the basis for reducing the Air Traffic Controller workload per aircraft. The progressive delivery of automation solutions will gradually increase the overall performance of the ATM system.

SESAR's automation solutions support air traffic flow and complexity management (ATFCM), pre-tactical planning and tactical control

Solutions listed here support the recommendations of the AAS in the areas of automation and productivity tools.

ID	Title	Description	Delivered in
#5	Extended arrival management (AMAN) horizon	Operational procedures and technical specifications for the integration of the information from arrival management systems operating out to an extended distance to provide an enhanced and more consistent arrival sequence. The system helps to reduce holding by absorbing some of the queuing time further upstream well into En Route. Includes integration of traffic departing from within the AMAN horizon of the destination airport. In Step 1, the 'newly' impacted En Route sectors are expected to contribute to the sequencing towards a single TMA	SESAR 1 (PCP)
#18	CTOT and TTA	Transition from calculated take off time (CTOT) to CTOT & target time arrival (TTA) Consideration of TTA at Network Manager level for traffic planning activities (ATFCM measures) and distribution of the TTA through NOP in particular to the airport of destination for integration in the AMAN.	SESAR 1 (PCP)
#66	Automated support for dynamic sectorisation	Automated support for Dynamic Sectorisation provides supporting tools to areas with high traffic density to evaluate the most suitable Air Traffic Control airspace configuration (sectors). Dynamic Capacity Management allows adapting the capacity to traffic load by grouping and de-grouping sectors and managing the staff resources accordingly. Unused latent capacity can occur at all Flow Management Positions (FMP) during peak traffic times. Current tools facilitate the detection of overload but do not offer better options to deal with it.	SESAR 1 (PCP)

ID	Title	Description	Delivered in
#17	Advanced short ATFCM measures (STAM)	Advanced Short ATFCM Measures (STAM) supported by automated tools for hot spot detection at network level enabling ANSPs to optimise traffic throughput. Advanced STAM are built on the basis of STAM deployment (hotspot, coordination tool, occupancy traffic monitoring values). The enhancements foreseen focus on improved predictability of operations, including sib/iRBT supported traffic and complexity prediction, weather, airport operations (departure sequences, ground handling, gate management, runway usage), what-if function and network capabilities.	SESAR 1 (PCP)
#20	Collaborative NOP	A Collaborative NOP Information structure (information model, classification by types of actions, influencers, performance objectives, relationships between actions, objectives, issues, etc.) will be available. The Collaborative NOP will be updated through data exchanges between Network Manager and stakeholders systems to the required level of service. This will enable the Network Manager and stakeholders to prepare and share operational decisions (e.g. TTA, STAM) and their justifications in real-time.	SESAR 1 (PCP)
Candidate solution #45	Enhanced network traffic prediction and shared complexity representation	The solution aims at improving the accuracy of the network manager traffic prediction from medium-term planning phase (D-2) to execution (included), relying in particular on new trajectory management features such as the preliminary FPL. It shall adapt existing methodologies and algorithms for demand prediction and regional complexity assessment.	SESAR 2020 Wave 2
#19	Automated support for Traffic complexity detection and resolution	Automated tools support the ATC team in identifying, assessing and resolving local complexity situations. It relies on a real time integrated process for managing the complexity of the traffic with capability to reduce traffic peaks through early implementation of measures for workload balancing Traffic Complexity Assessment and Individual Traffic Complexity based solutions	SESAR 1 (PCP)

ID	Title	Description	Delivered in
#37	Extended flight plan	The extended flight plan is an extension of the ICAO 2012 FPL. New information encompasses: - The 4D trajectory as calculated by the FOC flight planning system in support to the generation of the operational flight plan. The 4D trajectory information in not limited to 4D points. It contains additional elements for each point of the trajectory such at speeds, and aircraft mass; - Flight specific performance data: the climbing and descending capabilities of the aircraft specific to the flight. Short term use cases for EFPL are: - Use extended flight plan information to improve the process of validation of flight plans by the Network Manager, in particular by reducing the number of flight plan rejections resulting from the low resolution of the ICAO 2012 flight plan; - Use extended flight plan information to improve traffic predictions for traffic flow/complexity management; - Use extended flight plan information to improve ATC processes (traffic prediction, detection/ resolution of conflicts, AMAN operations).	SESAR 1 (PCP)
#27	Enhanced tactical conflict detection & resolution (CD&R) services and conformance monitoring tools for en-route	This SESAR Solution consists of innovative approaches that provide the en-route controller with two separation provision services: First, an enhanced monitoring conformance service (MONA) for both tactical and planning controllers. Compared to the existing MONA, this SESAR Solution includes a new alert to take into account lateral deviation and the rate change monitoring in climbing and descending phase to minimise false alerts. Second, a conflict detection and resolution service fully dedicated and designed for the tactical controller with a conflict detection service down to flight level 100. This service is based on effective clearances and specific ergonomics and use developed for the tactical controller, but also available and usable for the planning controller	SESAR 1

ID	Title	Description	Delivered in
Candidate solution #1	Next generation AMAN for 4D environment	This solution will provide enhancements to the arrival management systems and procedures in the context of digitalisation in ATM: uplink of AMAN constraints, uplink of a STAR or custom arrival route to the aircraft via ATN B2 from the ATSU, potential use of maximum descent speeds, etc. It investigates strategies to increase the use of managed/automatic mode for flights handled by TTL/TTG during sequencing, improved consideration of downlinked aircraft data by AMAN algorithms, use of machine learning for the refinement of AMAN algorithms, etc.	SESAR 2020 Wave 2
Candidate solution #8	Dynamic E-TMA for advanced continuous climb and descent operations and improved arrival and departure operations	The objective of this solution is to improve descent and climb profiles in busy airspace, as well as the horizontal flight efficiency of arrivals and departures, while at the same time ensuring traffic synchronisation, short-term DCB and separation. This requires a very broad scope, which includes advances in airspace design, development of ground tools, and development of ATC and airborne procedures.	SESAR 2020 Wave 2
Candidate solution #48	Digital integrated network management and ATC planning (INAP)	The SESAR solution 'digital INAP' aims at filling the gap between the management of traffic flows at network level (dDCB) and the control of flights in individual sectors. The solution develops and integrates local functions and associated tools, roles and responsibilities providing an automated interface between local NM and ATC planning to assist controllers in alleviating traffic complexity, traffic density, and traffic flow problems.	SESAR 2020 Wave 2
Candidate solution #53	Improved ground trajectory predictions enabling future automation tools	The solution focuses on the operational validation of improved CD&R tools. The main goal is to increase the quality of separation management services reducing controller workload and separation buffers and facilitating new controller team organisations. The foundation is the improvement of the ground TP (EPP data beyond weight and CAS, known MET data or new MET data and capabilities, etc.).	SESAR 2020 Wave 2

ID	Title	Description	Delivered in
Candidate solution #57	RBT revision supported by datalink and increased automation	The solution aims at supporting a continuous increase in the amount and the usefulness of information shared between air and ground and of the level of automation support to controllers and pilots, e.g. towards the automatic uplink of clearances with or without previous controller validation and towards increased use of the auto-load to FMS of uplinked clearances and of managed/automatic mode by the flight crew.	SESAR 2020 Wave 2
Candidate solution #96	HMI interaction modes for ATC centre	The solution addresses the development of new human machine interface (HMI) interaction modes and technologies in order to minimise the load and mental strain on controllers in the ATC centre. The SESAR solution shall consider modern design and development approaches and methodologies such as modularity, SoA, adaptive automation, etc. The new HMI interaction modes include the use of in-air gestures, attention control, user profile management systems, tracking labels, virtual and augmented reality, etc.	SESAR 2020 Wave 2
Candidate solution #56	Improved vertical profiles through enhanced vertical clearances	The objective of this solution is to develop an automation support for ATCOs to issue vertical constraints that support more efficient flight profiles while ensuring separation provision. First step, for flight still in climb, enhanced prediction of vertical profile data are presented to ATCOs to facilitate decision making. In a second more advanced step, the ATC system would generate proposals for conflict-free clearances that take anticipated aircraft performance into account, which can be uplinked to the flight crew by ATCO.	SESAR 2020 Wave 2 partly

E.3 Focus Area 2: Scalability & Resilience

E.3.1 Virtualisation and ATM data services

A virtual centre is one or more Air Traffic Service Units using ATM data services provided remotely. The concept provides for geographical decoupling between ATM data service providers and ATSUs. One ATSU may use ATM data services from multiple providers, just as one data provider may serve multiple ATSUs.

The ATM data services provide the data required for ATS. It includes functions like flight correlation, trajectory prediction, conflict detection and conflict resolution, arrival management planning. These services rely on underlying integration services for weather, surveillance and aeronautical information. They also include the coordination and synchronisation of ATM data in function of all trajectory interactions by the providers of ATS.

Solutions listed here support the recommendations of the AAS in the areas of virtualisation and ATM data services.

ID	Title	Description	Delivered in
PJ.16-03	Work station, service interface definition & virtual centre concept	Work Station, Service Interface Definition & Virtual Centre Concept will provide an operating environment in which different ATS units, even across different ANSPs, will appear as a single unit and will be subject to operational and technical interoperability. It includes the develop the ATSU architecture from a service-oriented approach with a focus on the technical services and common interfaces. Based on the Virtual Centre concept, the CWP/HMI needs to interface with one or more information service providers or consumers. A high performing and reliable underlying communication infrastructure may be needed. This solution encompasses En-route and TMA and airport/TWR environments.	SESAR 2020 Wave 1
Candidate solution #93	Delegation of airspace amongst ATSUs	The objective of this solution is to explore the different possible delegation of airspace amongst ATSUs based on traffic / organisation needs (either static on fix-time transfer schedule (Day/Night) or dynamic e.g. when the traffic density is below/over certain level) or on contingency needs. The solution covers an operational thread, which aims at defining and validating the different types of delegation of airspace and a technical thread, which aims at specifying the impacts of the operational thread on	SESAR 2020 Wave 2

ID	Title	Description	Delivered in
		the services defined in the Virtual centre concept.	
Candidate solution #101	SWIM TI [103]green profile for G/G civil military information sharing	The solution aims at enabling Ground/Ground civil – military SWIM based coordination at SWIM technical infrastructure level through SWIM profiles with an adequate quality of service, including (cyber) security/ resilience, needed by military stakeholders and agreed by civil stakeholders.	SESAR 2020 Wave 2
Candidate solution #88	Trajectory prediction service	This solution is a technical service conceived as being provided to Europeans ANSPs, AUs, AO, Military and the Network Manager (NM) in support of trajectory operations. The solution is intended to provide a single point of truth for a specific trajectory in the time frame from creation in long term pre-flight planning through to the flight execution phase. The solution is not intended to replace today's flight data processing systems and consequently the service can be used as an input to ATC systems but not used directly for control purposes.	SESAR 2020 Wave 2 partly

[103] System Wide Information Management Technical Infrastructure

E.3.2 Dynamic management of airspace

Dynamic management of airspace incorporate all airspace elements – such as en-route and terminal ATS routes, conditional routes, airspace reservations and ATC sectors – into new forms of airspace configurations designed to be dynamically managed, to respond flexibly to different performance objectives which vary in time and place. It provides a processes that supports the use of more dynamic and flexible elements, and describing a seamless, Network collaborative decision making (CDM) process, which balances demand and capacity by dynamically reconfiguring airspace and allows for the continuous sharing of information among all ATM partners enabled by SWIM.

Solutions listed here support the recommendations of the AAS in the area of dynamic management of airspace.

ID	Title	Description	Delivered in
Candidate solution #40	Mission trajectories management with integrated dynamic mobile areas type 1 and type 2	The objective of the solution is to improve the use of airspace capacity for both civil and military users and the efficiency of airspace management by introducing more automation and increased flexibility in the civil-military coordination. The solution delivers improvements to the planning phase of the mission trajectory, including the connection of MT management with the booking of ARES (in the context of this solution DMA Type 1 and Type 2), for which the WOC will be the key actor. The coordination between WOC and regional NM is a key element for this solution.	SESAR 2020 Wave 2
Candidate solution #44	Dynamic airspace configurations (DAC)	The objective of the solution is to improve the use of airspace capacity by increasing the granularity and the flexibility in the airspace configuration and management within and across ANSPs' areas of responsibilities. This solution will address the integration of concepts and procedures to allow flexible sectorisation boundaries to be dynamically modified based on demand. This includes potential implications for ATCO licences, international boundaries and potentially IOP and A/G multi-datalink communication capabilities.	SESAR 2020 Wave 2

E.3.3 Flight centric operations

The flight-centric concept changes the responsibility of the ATCO from controlling a piece of airspace to controlling a number of flights along their respective trajectories. Several executive controllers share responsibility over a flight-centric area. Incoming flights will be allocated according to a pre-established logic (such as flights interaction, traffic flows or complexity) to the least busy controller, thereby achieving a more balanced distribution of workload and improved scalability.

The solution listed here supports the recommendations of the AAS in the area of flight centric operations.

ID	Title	Description	Delivered in
Candidate solution #73	Flight-centric ATC and improved distribution of separation responsibility in ATC	The solution covers a concept that consists of assigning aircraft to ATCOs without references to geographical sectors, and have the aircraft controlled by that same ATCO across two or more geographical sectors. The solution requires flight-centric specific allocation, visualisation (traffic filtering), coordination tools (e.g. in the event of a conflict, establish which controller is responsible for its resolution) and, for high traffic densities advanced CD&R tools (that are not flight-centric specific). The solution also covers the concept of collaborative control with planned boundaries in which sectors are retained as they are today, with aircraft being assigned to a sector according to its geographic location. The boundaries between sectors have planned coordination conditions like in current operations, but with some additional flexibility by allowing controllers to issue clearances without prior coordination to aircraft in a different sector.	SESAR 2020 Wave 2

E.3.4 Sector independent controller training and licensing

SESAR is researching how to overcome current ATC sectors limitations by expanding the number of sectors that a controller can be validated for by providing automation support so that controllers' in-depth knowledge of the local area can be progressively complemented by the system. For instance, research is investigating how to validate controllers to work with a specific system and traffic complexity, regardless of the geographical area where the service is delivered.

Solutions listed here support the recommendations of the AAS in the area of sector independent Air Traffic Services.

ID	Title	Description	Delivered in
PJ.16-03	Work station, service interface definition & virtual centre concept	Work Station, Service Interface Definition & Virtual Centre Concept will provide an operating environment in which different ATS units, even across different ANSPs, will appear as a single unit and will be subject to operational and technical interoperability. It includes the develop the ATSU architecture from a service-oriented approach with a focus on the technical services and common interfaces. Based on the Virtual Centre concept, the CWP/HMI needs to interface with one or more information service providers or consumers. A high performing and reliable underlying communication infrastructure may be needed. This solution encompasses En-route and TMA and airport/TWR environments.	SESAR 2020 Wave 1
Candidate solution #44	Dynamic airspace configurations (DAC)	The objective of the solution is to improve the use of airspace capacity for both civil and military users by increasing the granularity and the flexibility in the airspace configuration and management within and across ANSPs' areas of responsibilities. This solution will address the integration of concepts and procedures to allow flexible sectorisation boundaries to be dynamically modified based on demand. This includes potential implications for ATCO licences, international boundaries and potentially IOP and A/G multi-datalink communication capabilities.	SESAR 2020 Wave 2
Candidate solution #70	Collaborative control and multi sector planner (MSP) in en-route	The solution addresses the collaborative control with unplanned boundaries concept, in which the traditional requirement to coordinate traffic at all sector boundaries is waived for an area covering two or more sectors. In case it is not completed in wave 1, the solution scope covers as well the development, for the en-route environment, of the concept of operation and the required system support e.g. coordination tools for operating in a	SESAR 2020 Wave 2

ID	Title	Description	Delivered in
		team structure where a Planner has responsibility for the airspace under the executive control of two or more independent Executive Controllers (multi-sector planner or MSP). The MSP is able to adjust the internal (executive) sector boundaries so that workload is balanced between the Executive controllers.	
Candidate solution #73	Generic controller validations	The current operation generally expects that controllers hold both a licence for a particular “discipline” (e.g. Area Control, Aerodrome Control etc.) and then a number of sector “validations” which permit that person to exercise their license in defined volumes of airspace. The SESAR solution “Generic controller validations“ aims at developing and validating advanced tools and concepts providing a more flexible ATCO validation regime that will allow ATCOs to be endorsed to work in a larger number of sectors than they do today, and therefore broaden the controller-licensing scheme. The work shall be focused on the identification, development and specification of the required human, system and procedural enablers. This shall address other aspects beyond the pure sector and separation management and will include information needs, support in emergencies, fall-back modes of operation, etc. The solution shall address potential new training strategies to ensure the acquisition of future ATCO competences in generic environments e.g. technical and psychological training to cope with higher levels of automation.	SESAR 2020 Wave 2
Candidate solution #88	Trajectory prediction service	This solution is a technical service conceived as being provided to Europeans ANSPs, airspace users (AU)s, AO, Military and the Network Manager in support of trajectory operations. The solution is intended to provide a single point of truth for a specific trajectory in the time frame from creation in long term pre-flight planning through to the flight execution phase. The solution is not intended to replace today’s flight data processing systems and consequently the service can be used as an input to ATC systems but not used directly for control purposes.	SESAR 2020 Wave 2 partly

E.3.5 CNS Enhancements

The decoupling of integration services and underlying CNS infrastructure services, allows for a performance based approach to CNS, as defined in the ATM Master Plan. CNS solutions will have to be packaged or merged in a way that guarantees to end users the availability, integrity, safety, security and other performance requirements to be mandated by the relevant authority. One way to reach this objective is to apply the service approach to the CNS provision.

In particular, frequency congestion on sector frequencies is a well-known constraint. Voice communication tasks represent between 35% and 50% of the tactical (executive) controller's overall workload. Considering the predicted exponential growth of the number of flying vehicles in the European airspace, migration to a data driven exchange is necessary. Increased and more complex information exchange between controllers and pilots demands the use of modern communications technologies. Voice is not capable to efficiently convey the information required for future operational procedures.

The use of data communication medium like CPDLC offers the potential to relieve congestion, enhancing existing communications between the air and the ground, and offering unambiguous transmission of routine messages between controllers and pilots. CPDLC contributes to reducing the pilot's and the air traffic controller's workload and allows them to concentrate on other essential tasks. **Therefore, it is highly recommended to move to datalink as primary means of communication**.

Solutions listed here support the recommendations of the AAS in the area of CNS Enhancements.

ID	Title	Description	Delivered in
#109	Air traffic services (ATS) datalink using iris precursor	The Iris Precursor offers a viable option for air traffic services (ATS) datalink using existing satellite technology systems to support initial four-dimensional (i4D) datalink capability. The technology can be used to provide end-to-end air-ground communications for i4D operations, connecting aircraft and air traffic management ground systems.	SESAR 1
#114	Cooperative surveillance ADS-B / WAM	Air traffic surveillance systems use both cooperative and non-cooperative techniques to locate aircraft. While non-cooperative techniques rely on the reflection of energy directed at the aircraft, cooperative techniques require the carriage of a transponder or transmitter device on board the aircraft. Systems using the signals broadcast from such transponders / transmitters are classified as a cooperative independent technology, as the ground surveillance systems derive all surveillance information from the decoded message content to determine aircraft identity and 3D position. Systems, such as ADS-B, in which the aircraft transmits its own position are classified as a cooperative dependent technology.	SESAR 1

ID	Title	Description	Delivered in
Candidate solution #57	RBT revision supported by datalink and increased automation	The solution aims at supporting a continuous increase in the amount and the usefulness of information shared between air and ground and of the level of automation support to controllers and pilots, e.g. towards the automatic uplink of clearances with or without previous controller validation and towards increased use of the auto-load to FMS of uplinked clearances and of managed/automatic mode by the flight crew.	SESAR 2020 Wave 2
Candidate solution #60	FCI terrestrial data link and A-PNT enabler (L-DACS)	The solution constitutes the future terrestrial A/G and A/A data link solution, which is one of the 'ICAO technologies', and supports the increasing ATM performance requirements (due to the growth of air traffic and its complexity). L-DACS constitutes a potential component of the A-PNT to support positioning and navigation requirements in PBN/RNP operations in case of a GNSS degradation or outage.	SESAR 2020 Wave 2
Candidate solution #76	Integrated CNS and spectrum	The solution addresses the CNS cross-domains consistency in terms of robustness, spectrum use and interoperability including the civil-military aspects through the provision of a global view of the future communications, navigation and surveillance services and the definition of the future integrated CNS architecture (and the CNS spectrum strategy).	SESAR 2020 Wave 2
Candidate solution #77	FCI services	The Solution will allow the real-time sharing of trajectories, timely access to ATM data and information services and the support to SWIM. The 'Communication Services' will support ATN-B1, ATN-B2 ATS services, and be expandable to support advanced ATM applications such as ATN-B3 ATS services. It will support AOC services and digital voice (VoIP) services. The Communication Services will be delivered using ATN/IPS and will allow interoperability with ATN/OSI protocols.	SESAR 2020 Wave 2
Candidate solution #101	SWIM TI green profile for G/G civil military information sharing	The solution aims at enabling Ground/Ground civil – military SWIM based coordination at SWIM technical infrastructure level through SWIM profiles with an adequate quality of service, including (cyber) security/ resilience, needed by military stakeholders and agreed by civil stakeholders.	SESAR 2020 Wave 2

Annex F Regulatory Assessment

Disclaimer: *The regulatory assessment presented in this study has been developed by the contractors and does not represent the views of the European Commission. It should be noted that only the Court of Justice of the European Union is competent to authoritatively interpret Union law.*

F.1 Overview

F.1.1 Context and approach

This annex presents a regulatory assessment of the three "conditions for success" from Section 5 with the aim of highlighting their legal feasibility within the existing regulatory framework. Where necessary, potential regulatory changes that would facilitate implementation are identified.

The three themes considered are:

i. **Capacity-on-demand (see Section 5.1):** Increasing resilience of Air Traffic Management (ATM) through horizontal collaboration between air traffic service providers (ATSPs). More generally, enabling cross-FIR provision of air traffic services (ATS).
ii. **ATM data service provision (see Section 5.2):** Decoupling ATM data services from Air Traffic Services (ATS) provision.
iii. **Targeted incentives for early movers (see Section 5.3):** Rewarding early movers supporting the implementation of new delivery models or high impact operational improvements.

These themes have been addressed from a legal angle and assessed against the regulatory framework governing ATM. For the purposes of the regulatory assessment, the legislation considered most relevant is listed in Annex B.

Whilst the study targets the ECAC geographical airspace, the regulatory assessment focused on the ICAO, SES and EASA regulatory regimes. As a consequence, the possible specificities of the oceanic zones have not been taken into consideration (as, in application of Article 1(3) of the airspace Regulation (EC) No 551/2004, the geographic scope of SES is "*the airspace within the ICAO EUR and AFI regions where Member States are responsible for the provision of air traffic services*").

F.1.2 Summary of results

F.1.2.1 Capacity-on-demand and cross-FIR ATS provision

This concept is about increasing resilience of the Air Traffic Management System by enabling horizontal collaboration between Air Traffic Service Providers (ATSPs).

A basic principle of the Chicago Convention is sovereignty with respect to national territory, including the national airspace[104]. But sovereignty also means that States, for reasons of efficiency gains and operational needs, have the right to engage into commitments with each other, with supranational organisations like the EU, or intergovernmental organisations like Eurocontrol, without giving up

[104] Article 1 of the Chicago Convention

their international State responsibility for ATM. This is also true for the part of the FIRs that extend over part of the sea beyond ground boundaries (E.g. FIR Brest, UIR Lisboa, etc.)

Article 3 of the Airspace Regulation[105] required the Commission to submit by 4 December 2011 a recommendation towards the establishment of a single EUIR (European Upper Area Information Region)[106]. This recommendation was not implemented and was partly at the origin of the present study. This situation can be explained partly by the difficulty inherent to the UIR ICAO notion that entails responsibilities that are not required for an efficient European airspace architecture. Paragraph (3) of the Article indicating respectively "*the establishment of the EUIR shall be without prejudice to the responsibility of Member States for the designation of ATSPs for the airspace under their responsibility*" contained, if not internal contradictions with the concept, at least limitations that rendered the concept extremely difficult to materialise effectively.

Without prejudice to the possible usage of the EUIR name outside of its ICAO context, this study demonstrates that based on a new concept of operations and modern technology, it is possible to achieve most of the goals underpinning the EUIR concept with the existing regulatory framework, in a more flexible and adaptable way.

Cross-FIR and cross-border ATS provision, which is necessary for the "capacity-on-demand service" detailed in Section 5.1, and also supporting the optimisation of airspace configuration detailed in Focus Area 1 as well as the dynamic airspace configuration, dynamic capacity management and the sector-independent Air Traffic Service Provision detailed in Focus Area 2, is possible within the existing ICAO, EASA and SES regulatory framework:

- Cross-FIR ATS provision within the same State is a matter for the State and the designated ATS provider to organise, and there is no legal obstacle to overcome.
- ATS provision across borders is allowed both under ICAO and the SES framework through the certification and designation processes embedded in Articles 7, 8, 9 and 10 of the Service Provision Regulation[107].
- The current arrangements for en-route charging explicitly allow the setting of cross-border charging zones, thus covering the charging aspects of cross-border ATS provision[108].

A number of topics would however require further consideration:

- Oversight, responsibility/liability: In a cross-border ATS provision context, extending across the airspace of more than one Member State, States' ability to ensure adequate oversight of

[105] Regulation (EC) No 551/2004 of the European Parliament and the Council of 10 March 2004 on the organisation and use of the airspace in the SES, as amended.

[106] A FIR or UIR being "*a three-dimensional area in which aircraft are under control of usually a single authority*" (source: Eurocontrol Lexicon of ATM terms: https://ext.eurocontrol.int/lexicon/index.php/Flight_Information_Region, based on ICAO official definition in AN 2 Rules of the Air 2005).

[107] Regulation (EC) No 550/2004 of the European Parliament and of the Council of 10 March 2004 on the provision of air navigation services in the single European sky (the service provision Regulation)

[108] Commission implementing Regulation (EU) No 391/2013 of 3 May 2013 laying down a common charging scheme for air navigation services (the charging Regulation), Recital 15 and Article 5(4). Also, see Article 21(4) of the draft new Performance and charging Regulation that received a positive opinion from the Single Sky Committee on 17 December 2018.

the service providers, and also responsibility / liability issues, should be addressed. To this effect, guidance material at European level would be helpful. Existing material, e.g. within Eurocontrol, could be used as a starting point.

- Interoperability: Intensification of cross-border ATS provision activities and in particular "capacity-on-demand" may require further harmonisation measures to secure an optimal level of interoperability between systems and may require a delegated act to be elaborated, in application of Articles 42, 43 and 45 on ATM/ANS systems and ATM/ANS.
- ATCO Licensing: Dynamic cross-FIR ATS provision and the capacity-on-demand service require the regulatory framework to be reviewed in view of exploring generic ATCO licensing, training needs and in particular the minimum number of hours to be performed to maintain the qualification, as well as the ways to organise this. This topic appears to be manageable in an environment with common attributes and tools on how to manage airspace in common as well as a common data layer.
- Pricing / charging: Whilst the current arrangements for charging explicitly allow the setting of cross-border en-route charging zones, the issue of calculating the costs, determining the price, and ensuring recovery through charges for the capacity-on-demand services remains to be examined. Guidance material at European level would be desirable and, depending on the findings of this examination, a regulatory change may be required.

F.1.2.2 ATM data service provision

This concept is about decoupling ATM data service provision from other Air Traffic Services (ATS).

The existing and applicable regulatory framework allows for the creation of ATM data service providers (ADSP)s and delegation by "legacy" ANSPs of services to other entities, subject to the overarching principle of international State responsibility for ATM/ANS.

Through draft Article 35 of the new draft Commission implementing Regulation on performance and charging schemes[109] the SES regime even encourages this "decoupling" and the implementation of market conditions.

The ADSPs could operate either as a "joint venture" type of partnership of existing ANSPs or as a certified external entity providing service in market conditions. The transition steps could therefore start being developed without major legal obstacles.

A number of topics would however require further consideration:

- Certification, oversight and enforcement: The EASA Basic Regulation and the Common Requirements Regulation organise these functions. The range of options for ADSPs would include both NSA and EASA being competent authority for oversight. The details of oversight arrangements will need to be confirmed through a proper examination once the definition of the ATM data services becomes clearer.
- Common Requirements for certification purposes: Building on the on-going work in the SESAR programme and possibly accelerating the innovation lifecycle, the services to be provided by ADSPs need to be precisely identified and defined (involving EASA and

[109] Which received a positive opinion from the Single Sky Committee on 17 December 2018 and has now entered the process of formal Commission approval.

associating the industry / stakeholders). On such basis EASA should develop the requirement for the certification of ADSPs, create a specific Annex for this purpose and as necessary review and update the existing annexes of the Common Requirements Regulation 2017/373.

- Alliance building: When the envisaged models, or possibly other models, become more concrete, it may be useful to consider adapting the SES regime to provide a more solid basis for alliance building between ANSPs, including the establishment of joint ventures, for example through guidelines.
- Competition rules: A detailed analysis is needed to establish whether and to what extent EU competition law may apply and what would be the consequences. Depending on its outcome, such study may affect the acceptability by stakeholders of the various models identified. This study should be carried out in the light of precedent cases and the recent evolution of the understanding by the European Court of Justice of the concept of "undertaking". The study should also weigh the two trends underpinning the SES packages with on the one hand the connection of ATS provision activities to the exercise of public functions[110] and, on the other hand, the explicit intention within the SES legislative packages to open progressively ANS provision to "market conditions"[111] and incentivise such evolution.
- Interoperability and data access: appropriate initial standards in relation to data exchange format have been developed in the context of SESAR and promulgated at ICAO level. Work is on-going to further develop interoperability means to secure safe, seamless and efficient processing of data between providers, and between providers and users of these services including access to and protection of data.
- Pricing/charging: Charging, or, in a broader sense, the design for a pricing mechanism require further analysis and may have to be adapted to support timely achievement of the proposed airspace architecture.
- Liability: Liability for the compensation of damages caused by ADSPs and other service providers remains a sensitive subject, which should be addressed, preferably at EU level.
- Other topics: Attention should also be paid to related questions which include, but are not limited to, data which must be made available in case of accident for investigation purposes, interoperability of data systems, property rights with respect to data, and their storage, and the protection of data against cybersecurity threats.

For these reasons, the regulatory and certification framework for ADSPs should be further developed, within both the SES and the EASA regulatory frameworks, also taking into account interoperability and performance requirements.

[110] Recital (5) of the service provision Regulation: "*The provision of air traffic services, as envisaged by this Regulation, is connected with the exercise of the powers of a public authority, which are not of an economic nature justifying the application of the Treaty rules of competition.*"

[111] In particular Article 3 of the charging Regulation (EU) No 391/2013. Also, see Article 35 of the draft new Performance and charging Regulation that received a positive opinion from the Single Sky Committee on 17 December 2018, broadening the possibility of submitting Air Navigation Services to market conditions and in particular now explicitly including ATM Data services.

F.1.2.3 Targeted incentives for early movers

This part of the study addresses the possibilities of rewarding those early movers supporting the implementation of new delivery models or of high impact operational improvements

The existing SES framework already contains incentive schemes aiming at supporting a timely and synchronised deployment of technology, in particular modulation of charges to support avionics equipage[112] and also a different treatment of restructuring costs within the performance scheme [113]. Furthermore the Common Project legislation provides public funding via the relevant Union funding Programmes[114], "*to encourage early investment from stakeholders and mitigate deployment aspects for which the cost-benefit analysis is less positive*". The European Investment Bank (EIB) has developed a range of financial instruments to support SESAR deployment.

However, within the scope of the present study, the scale of the necessary transformation and the need for synchronisation are much greater than for the current deployment needs. For this reason, it is recommended to review the existing incentivisation framework, also using the experience gained and lessons learned from the Pilot Common Project, and to develop and adopt an overall incentivisation policy that will provide genuine incentives to "early movers".

Section 5.3 of the study proposes a non-exhaustive list of potential incentive examples. Their assessment allows the following conclusions to be drawn:

- The issue of modulation of charges, already explicitly foreseen in the charging Regulation, should be reviewed with a fresh perspective, e.g. through the concept of lower charges financed by EU funding, or the concept of "pay per service used".
- The concept of Best Equipped Best Served, "BEBS", should be addressed with the idea of differential rather than preferential services and would require further analysis and most probably regulatory changes.
- Many of the study's proposals for incentives directed at service providers are largely possible under the existing legal framework:
  - Profit margin for 1-on-1 agreements on remote provision of ATS capacity;
  - Rewarding the achievement of specific KPIs;
  - Allowing faster cost depreciation of legacy assets (through alignment with the wording of Article 2.3.3.4 of the Eurocontrol Principles for establishing the cost-base for route facility charges and the calculation of the unit rates[115], or through the inclusion of costs linked to investments under "restructuring costs" that would generate comparable effects);
  - European guarantees for first movers;
  - Direct financial support with appropriate control mechanisms;

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

[113] Commission implementing Regulation (EU) No 391/2013 of 3 May 2013 laying down a common charging scheme for air navigation services, Articles 7(4) and 16.

[114] Commission implementing regulation (EU) No 409/2013 of 3 May 2013 on the definition of common projects, the establishment of governance and the identification of incentives supporting the implementation of the European Air Traffic Management Master Plan, Recital (20) and Article 13.

[115] https://www.eurocontrol.int/articles/reference-documents

- Making SESAR investments costs exempt from the performance scheme, subject to the implementation of appropriate and powerful control mechanisms.

One proposal raises more issues from a legal perspective:

- Direct financial support mechanisms to new ADSPs, where the possible applicability of State Aid law may deserve further study.

F.1.2.4 Recommendations from the National Supervisory Authorities (NSAs)

During the consultation process, meetings were held with a significant number of NSAs to collect their questions and requirements. This resulted in the drafting of a number of legal recommendations, which are listed in the Table below. They are fully in line with the conclusions and recommendations of this Annex:

Study recommendations	Legal recommendations collected from NSAs
Recommendation 1 – Launch airspace re-configuration supported by an Operational Excellence programme to achieve quick wins	• Issue EU guidance material to support the implementation of optimal cross-FIR redesign of sectors: addressing liability, performance and charging implications
Recommendation 2 – Realise de-fragmentation of European skies through virtualisation	▪ Issue EU guidance material to support the implementation of capacity-on-demand arrangements: addressing liability, performance and charging implications ▪ Request EASA to develop the regulatory and certification framework for ATM data services providers (ADSP) taking into account interoperability and performance requirements based on European and ICAO standards ▪ Request EASA to start preparing a potential update of the ATCO licensing scheme to support dynamic airspace configurations (anticipating SESAR 2020 results and building on current best practices)
Recommendation 3 – Create SES framework that rewards early movers	• Review incentivisation policy to reward actors who are the first to implement the proposed transition strategy

F.2 Enabling cross-FIR ATS provision and capacity-on-demand

The analysis in this chapter relates to Air Traffic Services (ATS), meaning "*The various flight information services, alerting services, air traffic advisory services and ATC services (area, approach and aerodrome control services)*"[116]. ATC services are "*Provided for the purpose of: (a) preventing collisions between aircraft and in the manoeuvring area between aircraft and obstructions; and (b) expediting and maintaining an orderly flow of air traffic*".[117]

The following paragraphs examine to what extent cross-border ATS provision and capacity-on-demand are feasible within the framework of the regulatory approach that exists today. It is important to note that the legal topics that must be addressed in order to assess the feasibility of cross-border service provision are the same, irrespective of the form this service provision takes (Be it permanent designation of ATS to a neighbour, temporary designation of ATS to a neighbour in a pre-arranged manner, or temporary designation of ATS via a capacity-on-demand service). The only difference is in the degree of complexity: the implementation of permanent designation of ATS to a neighbour, between two States, is easier to implement than large-scale and dynamic capacity-on-demand arrangements involving a large number of States. The latter justifies more guidance material and possibly harmonisation or updates of regulations (e.g. for ATCO qualification and training in the case of "capacity-on-demand"). This is detailed in this annex, but it should be stressed that the difference in the difficulty of implementation is in degree rather than in nature.

F.2.1 The overall sovereignty principle

The SES legislation confirms the general principle of sovereignty of States over the airspace above their territory, as provided for in the Chicago Convention.[118] The SES legislation also underlines the Member States' obligation to cooperate.[119]

The EU legislator decided, within the context of the common transport policy as provided for under the TEU and the TFEU (in particular Title VI TFEU), to integrate ATM progressively[120], recognising that "*It is essential to achieve a common, harmonised airspace structure in terms of routes and sectors, to base the (…) organisation of airspace on common principles, and to design and manage the airspace in accordance with harmonised rules". Furthermore, "adequate measures should be introduced to improve the effectiveness of air traffic flow management in order to assist existing operational units (…)."*[121]

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[116] Art. 2, para. 11 of Regulation (EC) 549/2004 of the European Parliament and of the Council of 10 March 2004 laying down the framework for the creation of the single European sky (the framework Regulation).
[117] Art. 2, para. 1 of Regulation 549/2004 as amended.
[118] Recital 5 of Regulation 551/2004 of the European Parliament and of the Council of 10 March 2004 on the organisation and use of the airspace in the single European sky, *OJ* L 96, 31.3.2004, pp. 20-25 as amended; Recital 4 and Article 1 §2 and §3 of Regulation 549/2004 as amended.
[119] See Art. 1 of Regulation 549/2004 as amended and Article 1 of Regulation 551/2004 as amended.
[120] Cf. Recital 3 of Regulation 551/2004 as amended, and Recital (2) thereof, with a reference to the report of the High Level Group considering that "*airspace should be designed, regulated and strategically managed on a European basis*"; see Article 1 , para. 1 of Regulation 551 as amended.
[121] Recital 18 of Regulation 551 as amended.

This study is part of this progressive approach. The envisaged dynamic management of airspace concept, described in Section 4.3.2.14.3.2.1, needs to be assessed against the SES – and the safety (EASA) – legislation. Other aspects of airspace design are to be dealt with at national or FAB level[122].

At present, the institutionalised cooperation between the Member States is framed within the FABs and safety cooperation (via EASA). However, "*Further cooperation and integration between service providers is promoted by the creation of control areas across national boundaries and the subsequent designation by Member States of service providers entitled to operate in such areas*"[123]. The SES legislation, although it has created the FABs, leaves room for other cross-border cooperation.[124]

F.2.2 Designation of ATS providers

F.2.2.1 Public law and State responsibility

As determined under the Chicago Convention, ATS is a State responsibility and the designation of the ATS provider a State competence.

In compliance with this, the SES-legislation provides for the designation of the ATS providers by the individual Member States. According to Article 8.1 of the Service Provision Regulation, "*Member States shall ensure the provision of ATS on an exclusive basis within specific airspace blocks in respect of the airspace under their responsibility. For this purpose, Member States shall designate an ATS provider (…)*". The "*designation*" of the ATS provider concerns the act by which a State provides the mandate for service provision to the ATS provider ("*the Designation Act*").[125] The Designation Act is a legal instrument that is binding upon the service provider.

F.2.2.2 Functional / operational responsibility of the ATS provider

A designated ATS provider has operational responsibility for the ATS in the airspace for which it has been designated by a designating State.

With the designation on an exclusive basis within a specific airspace block, the functional responsibility for the ATS provision within such block is given to one single provider, based on binding arrangements between the designating State and the provider. An ATS provider can be designated for the entire airspace of a State, or for a specific part thereof. Member States have discretionary powers to designate a validly certified ATS provider. In relation to the use of cross-border services, it

[122] Art. 6, para. 4, d) and para. 5 of Regulation 551 as amended.

[123] Communication from the Commission to the Council and the European Parliament on the creation of the Single European Sky, 11 December 20001, COM (2001) 564 final/2, s.2.13, 5.

[124] Cf. Proposal for a Regulation of the European Parliament and of the Council amending the SES Regulations in order to improve the performance and sustainability of the European aviation system, COREPER report to the Council, doc. 2008 /0127 (COD), 4 December 2008: "*In the interests of fostering cross-border cooperation, either via functional airspace blocks or through more ad hoc arrangements* (…)*".*

[125] The nature of such act depends on the applicable State law. One of the draft versions of the service provision Regulation contained a definition: "*'Designation' means an appointment by a Member State or Member States* (…) *which gives a service provider the responsibility for providing air traffic services on an exclusive basis."* See Communication from the Commission to the Council and the European Parliament on the creation of the Single European Sky, 11 December 20001, COM (2001) 564 final/2, draft version of the service provision Regulation.

is Member States' obligation to ensure that their national legal system allows the designation of a foreign ANSP.[126]

Member States must "*define the rights and obligations to be met by the designated air traffic service providers*".[127] Mostly this is done in the Designation Act: this Act may reiterate provisions from the national law of the designating State or from the applicable FAB agreement to make sure that they are binding upon the service provider, or may contain supplementary provisions.

The Designation Act will provide for the liability framework. The liability clauses and/or obligations for the service provider to reimburse compensation that the designating State paid due to an incident in the airspace above its territory are binding. The Designation Act can also contain liability limitations. The liability issues are specifically addressed in Paragraph F.2.3.

The Designation Act is important to determine the relationship between the State and the designated provider. Especially where a foreign service provider is designated by a State for parts of that State's airspace, it is advisable that the related Designation Act contains detailed provisions governing the relationship between the designating State and the provider.

F.2.2.3 Cooperation under Article 10 of the Service Provision Regulation

The SES legislation, in Article 10 of the Service Provision Regulation[128], provides for cooperation between ANSPs, who "*may avail themselves of the services of other service providers that have been certified in the EU*". "*ANSPs shall formalise their working relationships by means of written agreements or equivalent legal arrangements (…) to be notified to national supervisory authorities*". For ATS, the approval of the Member States concerned is required.

Article 10 of the Service Provision Regulation concerns a form of "subcontracting",[129] by which a Member State designates an ATS provider. This same designated ATS provider may avail itself of the services of another certified ANSP.

Although Article 10 of the Service Provision Regulation principally aims at allowing the sub-contracting of well-defined services rather than large-scale cooperation,[130] it also allows arrangements between ATSPs for subcontracting of air traffic services, subject to the approval of the Member States concerned. This is required for the implementation of cross-border ATS provision and "capacity-on-demand". The ATS provider that avails itself of the services of another ATS provider, with the approval of the States concerned, will maintain the operational responsibility and bear the related liability risks. The ATS provider that is providing the service in another State on the other hand will be subject to that State's laws and rules. For these reasons, guidance material and further harmonisation of rules would enhance legal certainty for reaching a more EU-wide approach of capacity-on-demand and large-scale cross-border service provision.

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[126] Art. 8, para. 2 of Regulation 550/2004 as amended.

[127] Art. 8, para. 3 of Regulation 550/2004 as amended.

[128] Regulation (EC) 550/2004 of the European Parliament and of the Council of 10 March 2004 on the provision of air navigation services in the single European sky (the service provision Regulation), *OJ* L 096, 31 March 2004, pp. 10-19.

[129] Sometimes this is referred to as "*sub-delegation.*"

[130] The Commission proposal has put emphasis on the subcontracting of ancillary, aeronautical information services and meteorological services rather than of air traffic services: see Communication from the Commission to the Council and the European Parliament on the creation of the Single European Sky, 11 December 20001, COM (2001) 564 final/2, 20; see also Commission of the European Communities, Amended proposal for a Regulation of the European Parliament and of the Council on the provision of air navigation services in the Single European Sky, COM(2002) 658 final, 9.

In case of cross-FIR ATS services under Article 10 of the Service Provision Regulation, involving more than one Member State, the involved States often jointly designate each of the ATS providers concerned for the airspace of the parent State. The ATS providers will then further set out the arrangements between them.

F.2.2.4 Functional Airspace Blocks (FABs)

FABs are established by mutual agreement between all Member States who have responsibility for any part of the airspace included in the block or by a declaration of one Member State if the airspace included in the block is wholly under its responsibility.[131] Agreements between the relevant Member States, where airspace blocks extend beyond national boundaries, are necessary to determine the details of the cooperation[132].

The existing FABs have various levels of ambition, depending on the State arrangements. Whilst some demonstrate a genuine endeavour to foster cooperation or even integration of a number of functions, this is not the case for others, which remain at a more formal/institutional level. The dynamic airspace configuration envisaged in this study requires flexibility to fully implement the proposed changes. To allow FABs to fully participate in the roll-out of the Study's recommendations, it should be envisaged to review and adapt (if necessary) the existing agreements so as to maximise dynamicity and resilience within the FAB.

F.2.2.5 Topics requiring further consideration

- In a cross-border ATS provision and "capacity-on-demand" context, States' ability to ensure adequate oversight of the designated ATS providers, and also responsibility / liability issues, should be addressed. To this effect, further guidance material at European level would be helpful.
- Dynamic cross-border ATS provision and the capacity-on-demand service require the ATCO regulatory framework to be reviewed in view of exploring generic ATCO licensing, and also training needs and in particular the minimum number of hours to be performed to maintain the qualification, as well as the ways to organise this. This issue appears to be manageable in an environment with common attributes and tools on how to manage airspace in common as well as a common data layer.
- Whilst the current arrangements for charging[133] explicitly allow the setting of cross-border charging zones, the issue of calculating the costs, determining the price, and ensuring recovery through charges for the capacity-on-demand services remains to be examined. Guidance material at European level would be desirable and, depending on the findings of this examination, a regulatory change may be required.

[131] Art. 5 of Regulation 551/2004 as amended.
[132] Cf. Art. 2 (3) of Regulation 550/2004 as amended
[133] Cf. Articles 5(2) and 5(4) of charging Regulation (EU) No 391/2013

F.2.2.6 Conclusions

- Cross-FIR and cross-border ATS provision, within or beyond FABs, is allowed under ICAO and explicitly encouraged in the SES legislation.
- The States remain sovereign and responsible in relation to their territory; designation acts can determine the applicable regime in a given airspace. The designation acts should address and sort out the topics of responsibility and liability.
- Article 10 of the Service Provision Regulation constitutes a valid legal basis for agreements between ATS providers in relation to cross-border ATS provision and “capacity-on-demand”, subject to State approval.
- Large-scale cooperation between ATS providers in a dynamic way, involving services in States other than the State that has designated them, and this in a systematic way within Europe - with in particular the “capacity-on-demand” concept - may justify a need for further harmonisation and clarification of respective operational responsibilities, with probably further EU legislative action.
- FABs should be invited to review their arrangements and adapt them as necessary to foster dynamicity and resilience of ATM within the FAB.
- Further guidance material would be desirable to bring clarity and guidance on topics such as oversight, liability issues (specifically addressed in 2.3 below), as well as, in a capacity-on-demand context, ATCO licensing (and in particular training) as well as costs, pricing / charging and recovery issues.

F.2.3 Liability

F.2.3.1 State responsibility and liability

The concept of “State responsibility” under international law arises when a conduct (act or omission) attributable to that State constitutes a breach of an international obligation. A legal obligation must thus exist under international law as the prerequisite for State responsibility. State responsibility does not necessarily require damage; the finding that a State’s conduct is contrary to an international obligation and is attributable to the State suffices to determine State responsibility, which therefore is not exactly the same as “State liability”. A State committing an internationally wrongful act is also liable for repairing, that is restitution in kind and where this is not possible anymore, satisfaction and/or compensation.

Under the Chicago Convention, States have a duty to guarantee adequate ATS provision above the territory over which they have sovereignty. Article 28 of the Chicago Convention renders the ratifying States responsible for the provision of ATS, whether operated by public or private entities. This Article implies responsibility of the States, not only for service provision, but also for the implementation of regulation where necessary, for safety oversight and enforcement of the air navigation services over their airspace.[134] A breach of such international obligation, that is attributable to the State under international law, may constitute “a wrongful act” that entails the international responsibility of that State: “*There is a breach of an international obligation by a State*

[134] Cf. analysis made by Eurocontrol: workshop on responsibility and liability in ATM, 14-15 November 2006; it however does not concern an absolute obligation; only “in so far as a State finds it practicable to do so”. It is possible for the ICAO Council to address the issue of a State not taking up such responsibility.

when an act of that State is not in conformity with what is required of it by that obligation, regardless of its origin or character."[135]

A violation of the Chicago Convention by a member State, by lack of provision of ATS, may hence trigger the international responsibility of that State, that is then under the obligation "*to make full reparation for the injury caused by the internationally wrongful act*". "*Injury includes any damage, whether material or moral, caused by the internationally wrongful act of a State*"[136]. The responsibility of a State under Article 28 of the Chicago Convention would thus result in liability of that State for defective ATS, as under general international public law, vis-à-vis the other States.[137]

The extent to which a private party could claim damages from that State will depend on the liability regime accepted by the State concerned. Some States still invoke immunities, as a matter of domestic law, but generally immunities will not apply for actions involving commercial activities.[138] Mostly States will enjoy immunity from criminal proceedings but not from civil proceedings.

In case of damage due to defective ATS, the question is thus whether the ATS provider will be liable or whether the State is also liable, or whether there is a joint liability. States are increasingly mandating bodies with a separate legal personality, public or private, with the related public service. In the proposed context, this body may even be located in a different State.

The SES legislation also aims at separating regulatory tasks from operational tasks, so that there is a transparent exercise of powers and appropriate oversight. It is generally recognised that States are free to choose their own organisational structure and legal form for their provision of ATS, if compliance with the Chicago Convention and SES - and EU safety – legislation is guaranteed.

Irrespective of the organisational form of the entity providing ATS, the State retains ultimate responsibility for safety under the Chicago Convention. It is deemed that defective ATS provision by an ATS provider in a given State, where it concerns a mandate for a public service mission, normally will involve also the liability of that State.[139]

For ATS, most States will be considered "primarily liable" for wrongful services by their designated providers, even though the designated provider is functionally responsible. The State in that case will normally have a right of recourse against the provider.[140] Some States apply a subsidiary liability of the State for the wrongful service provision by its ATS provider: the designated provider will then be liable in first instance, however mostly with an obligation of the State to compensate damage that exceeds the insurance coverage or financial capacity of the service provider.

[135] Article 12 of UN Articles on State Responsibility, Resolution on responsibility of States for internationally wrongful acts, A/RES/56/83.

[136] Art. 31, para. 1 and 2 of UN Articles on State Responsibility, Resolution on responsibility of States for internationally wrongful acts, A/RES/56/83.

[137] Art. 33, para. 1 of UN Articles on State Responsibility, Resolution on responsibility of States for internationally wrongful acts, A/RES/56/83.

[138] M. Sörensen, *Manual of public international law*, London, MacMillan, 1968, 930 pp., p. 430.

[139] Art. 5 of the UN Articles on State Responsibility: "*The conduct of a person or entity which is not an organ of the State (…) but which is empowered by the law of that State to exercise elements of the governmental authority shall be considered an act of the State under international law, providing the person or entity is acting in that capacity in the particular instance."*

[140] This depends on the applicable local laws and the applicable provisions in the Designation Act: the Designation Act may provide for such a right of recourse, or may cap the reimbursement obligation of the ATS provider

F.2.3.2 Liability of the ATS provider

In relation to the cross-border flexible cooperation between ATS providers, it could be envisaged to apply "*the effective service provider*" doctrine, where the provider that has directly caused damage is primarily liable for such damage. If it is a foreign provider, it is not impossible for the relevant arrangements to provide for jurisdiction of the courts of the State where the provider is based. However, since ATS mostly is considered a public service, the State on whose territory the damage occurs will mostly want to retain jurisdiction.

The ATS provider that provides its services in another State thus may be subject to different liability regimes. Liability regimes differ according to the applicable laws, and differ according to the nature of existing duties.[141] Regimes may also differ in relation to the burden of proof.[142] Liability can be contractual or non-contractual ("*tort*" or "*responsabilité civile*"); "*third party liability*", is a form of tortuous liability where more remote parties (those who are not "*privy*" to or cannot directly benefit from rights under a contract between other parties) such as victims on the ground, suffer injury: this exists in common law countries whereas civil law jurisdictions do not particularly distinguish this situation from normal tortious liability towards a co-contractor or third parties. Limitation periods for contractual and tortious claims also vary from State to State. In a number of countries, criminal liability may exist for corporations, for ATS providers, in addition to the civil liability.

F.2.3.3 Additional considerations related to certification and oversight

As a rule, the ATS provider needs to hold a certificate from the national supervisory authority of the Member State in which it has its principal place of operation and registered offices. The certificate must confer on the ATS provider the possibility of offering its services and being designated in another State. Member States shall mutually recognise each other's certificates. [143]

In case of cross-border ATS provision, the provision of this certificate may trigger the liability of the Member State of the NSA which delivered it if it is provided wrongfully. On the other hand the certificates may to a certain extent alleviate the liability of the ATS providers.[144]

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[141] Some duties of the ATS provider (e.g. the duty to respect standards or requirements) may trigger liability for fault, but in some States also strict liability. ATS providers also have a general duty of care towards the public.
[142] E.g. some faults may trigger liability if the fault is evidenced (e.g. obligation of means), others will trigger liability except if force majeure is evidenced (e.g. obligations of result).
[143] Article 7 of the service Provision Regulation; the new EASA Basic Regulation also provides for certification of ANSPs by the national competent authorities; certain alternative verifications of compliance are provided for under this Regulation.
[144] This is to be further examined since not part of the present study.

F.2.3.4 Conclusions on liability

- The liability topic in a cross-border ATS provision context requires specific arrangements, as it is necessary for ATS providers that provide services in the territory of a State that is not their originally designating State to clearly see which rules and laws they need to comply with and which liability regime applies.
- If these arrangements do not exist, the State that has the sovereignty over the territory where damage occurs will normally remain liable for the wrongful ATS provision.[145] The agreements between States on cross-border service provision may contain a right of recourse against the other involved State or /and the service provider.
- The differences between the liability regimes in the different Member States may constitute a problem for the implementation of the dynamic airspace configuration, as it may be difficult for ATS providers to be subject to different liability regimes when providing services in different Member States.
- This is why guidance material or a possible EU legislative initiative could consider and address liability regimes, which would then be implemented by the Member States even if they deviate from the normally applicable local liability regime.

F.2.4 EU legislation on interoperability

F.2.4.1 Oversight and verification

Besides the substantial requirements, the interoperability legal framework contains provisions on oversight and verification of compliance with the interoperability requirements. These aspects are currently still governed by the Interoperability Regulation, this until the necessary implementing acts under the new EASA Basic Regulation have come into force.[146]

Under the current regime, verification of compliance with the substantive interoperability provisions can be achieved through several methods:[147]

a) through EU specifications,[148] drawn up by the European standardisation bodies in cooperation with EUROCAE, or by Eurocontrol; application remains voluntary, or

b) through verification of compliance;[149] the Interoperability Regulation also provides for verification through a system of declarations. ANSPs must make a declaration of verification of systems wherein they declare that their system meets the essential requirements and the relevant implementing rules for interoperability.[150] Verification of these declarations is done on the national level by the “Notified Bodies”. The national supervisory authorities[151] have

[145] Art. 28 of the Chicago Convention often is referred to as being the basis for primary liability of the State in case of damage due to failure of ATS in the territory over which it has sovereignty, regardless of who is providing the service.

[146] or at the latest until 12 September 2023.

[147] Article 6a interoperability Regulation.

[148] Article 4 interoperability Regulation.

[149] See also https://ec.europa.eu/transport/modes/air/single_european_sky/community_specifications_en.

[150] Article 6 interoperability Regulation.

[151] *Ibid.*, Article 4.

the responsibility to take measures against constituents or systems that do not or no longer comply with the essential requirements.

Verification of interoperability can also be achieved through certification via the EASA technical framework[152]; certificates issued (in accordance with Regulation 216/2008, the old EASA Basic Regulation) shall remain valid and shall be deemed to have been issued, made and recognised pursuant to the new EASA Basic Regulation.[153] Until now, verification of compliance with the interoperability requirements has been exercised by the national authorities.[154]

The new EASA Basic Regulation rationalises this overlapping system of verification/certification.[155] ATM/ANS systems and constituents under the new Regulation must comply with the essential requirements of its Annex VIII (including the interoperability requirements) and with the detailed specifications established in delegated acts. Responsibility for the certification or the verification of the declarations lies with either the national competent authority or with EASA, depending on the provisions of the delegated acts.[156]

The cooperation between ATS providers will bring with it an increased activity of 'foreign' (intra EU) ANSPs operating within the territory of another Member State. Nonetheless, States remain internationally responsible for their acts on their territory. In case the certification/verification is still provided for by the Member States where the ATS provider has its principal place of operation, this would mean that certain Member States would incur international responsibility (and hence, depending on national law potentially also civil liability) for the activities of an ANSP that provides services on the territory of that Member State, but has its certification/verification performed by another Member State. Although, in line with Article 7(8) of the Service Provision Regulation No 550/2004, Article 67 of the EASA Basic Regulation provides that certificates issued by one Member State shall be valid in all Member States, compliance with the interoperability requirements requires an overview of the different systems, procedures and constituents in the different Member States, so that verification of compliance may rather be an EASA task.

Some certification, oversight and enforcement duties are anyway centralised with EASA[157] as "*the Agency shall be responsible for […] the certificates for the ATM/ANS providers […], where those providers have their principal place of business located outside the territories for which Member States are responsible under the Chicago Convention and they are responsible for providing ATM/ANS in the airspace above the territory to which the Treaties apply*" and "*the certificates for the ATM/ANS providers […], where those providers provide pan-European ATM-ANS*".

[152] Article 6a interoperability Regulation

[153] Article 140 new EASA Basic Regulation.

[154] Subject to certain exceptions, see art. 22a Regulation 216/2008 (old EASA Basic Regulation).

[155] Article 45 EASA Basic Regulation.

[156] Article 80, 2, c EASA Basic Regulation.

[157] Article 62 of Common Requirements Regulation in conjunction with article 80 EASA Basic Regulation.

Further EU/EASA measures may be needed to support the new dynamic airspace architecture and "capacity-on-demand" context in view of further harmonisation. It may also be necessary to adopt Union specifications via the EASA acceptable means of compliance, in order to keep a possibility of presumption of compliance.

F.2.4.2 Conclusion on interoperability

Appropriate initial standards in relation to data exchange format and services have been developed in the context of SESAR and are already partly promulgated at ICAO level.

To further strengthen the needed level of interoperability and allow the intended dynamic and flexible cooperation at EU level including "capacity-on-demand", further harmonisation initiatives can be as well considered by the EC and EASA.

F.3 ATM data service provision

F.3.1 Scoping the issue

The proposal aims at decoupling the ATM data service provision from the current vertical, 'silo' set up for ATS provision , so that ATM data services may be provided by other entities in the same way that is currently possible for ancillary services such as CNS and MET.

This section takes the current state of affairs as a starting point and discusses how to move from there to future potential options for ATS data service provision; three of which are described in Section 5.2 (Figure 19).

The idea is that these different models could co-exist depending on States' willingness and local specificities. Their legal implications are examined under the ICAO, SES and EASA regulatory regimes. In addition, for this specific issue, attention is also paid to:

- the EU competition law regime drawn up in the Treaty on the Functioning of the EU (TFEU), regulations and measures adopted under these provisions, as well as case law;
- civil liability rules on compensation of damages.

This is not to say that all legal aspects are covered by their examination under the above regimes. However, this Annex aims to provide a reasonably complete view and it is believed that the outcome will not be substantially affected by taking into account other legal regimes.

F.3.2 The proposals put forward in this study

Proceeding from the 'silo' model, the study has examined models pursuant to which ATM data service provision develops into an activity that may be carried out through ANSP alliances, separate service providers and in the most ambitious model, specialised service providers in a market-oriented environment. The starting point is the decoupling of ATM data service provision from the 'core' services provided by ATSPs; ATM data service provision is then provided by 'an entity' which is more or less separate / independent from the ATSP, according to the three identified models below, building on the description in Section 5.2 (Figure 19):

- **Model 1 – ANSP alliances:** ATSPs continuing to provide 'core' ATS services create 'alliances', a 'joint venture', referred to as a 'dedicated jointly owned entity', which is responsible for the provision of ATM data services in 'their' airspace.
- **Model 2**: **Separate integrated ADSP:** Certain ATSPs transfer all their data infrastructure, systems and operations to an independent entity from which they would "acquire" their ATM data services for a 'fair price';
- **Model 3**: **Specialised data service providers:** The entities are legally separate from the ATSPs and focus on certain parts of the "ATM data service" value chain and could be created through competitive entry or partial transfer of existing activities by the ATSP. In such model, it could be that, rather than buying and operating an ATM system, the ATSP buys the "ATM data service" (potentially from the manufacturer of the system).

It is acknowledged that the models are not intended to be exhaustive but illustrative and that they can be implemented simultaneously by different States or groups of States, or implemented with nuances. Their examination however allows getting a fair view on the applicability of basic models, which can then by applied to intermediate or different ones.

F.3.3 Legal acceptability of the models of decoupling

F.3.3.1 The relationship between ATSP and ADSP

The creation of an ADSP could be decided by legal, prescriptive, obligations similar to the ones adopted in other regulated activities. In this respect, the “decoupling” provisions established in rail transport[158] or energy[159] legislation (separation of network management from service provision, and separation of accounts) could serve as examples.

More flexibly, the study proposal uses the verb ‘decouple’ in the sense of moving towards a situation where ADSPs are legally decoupled/separated from the ATSPs, should the ATSPs, and the States which have certified them, wish to proceed to this step. ADSPs are supposed to ‘work on their own’, in a legal entity which is separate from the legal form of the ATSP. The decoupling can result in different modes of relationship between ATSP and ADSP, which are examined in the present section.

F.3.3.2 Possibility under the Chicago/ICAO and SES regimes

Subject to the maintenance of the overriding principle of international State responsibility and the conclusion of inter-State agreements on such a step, this “decoupling” is allowed under the Chicago/ICAO regime.

Further to this regime, it is also allowed – and even encouraged - under the SES regime with the gradual development of the concept of “market conditions” and in particular the recent and explicit addition of “*ATM data service provision*” to the list of services that may be submitted to market conditions in Article 35 of the draft Commission Regulation on performance and charging[160].

It should also be noted that Recital 5 of EU Regulation 550/2004 as amended postulates that the provision of ATS “*is connected with the exercise of the powers of a public authority, which are not of an economic nature justifying the application of the Treaty rules on competition.*”[161]. This element is to be borne in mind when addressing the issue of potential application of EU competition Law, as is done in F.3.4.5 below.

F.3.3.3 The issues of certification and supervision

Whilst certification and supervision (oversight) of ATM/ANS provision and providers remains in principle a task for national NSAs, the EASA Basic Regulation (EU) 2018/1139 provides for the reallocation of such functions from Member States to EASA[162] for:

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[158] Council Directive 91/440/EEC of 29 July 1991 on the development of the Community's railways, *OJ* L 237, 24/08/1991, pp. 25-28.

[159] Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC, *OJ* L 211, 14/08/2009, pp. 55–93.

[160] Which received a positive opinion from the Single European Sky on 17 December 2018 and is, at the time of drafting this document going through the process of formal approval by the College of the Commission.

[161] See also, Art. 1, para. 1 of EU Regulation 549/2004, and Art. 9(a) of Regulation (EU) 2018/1139.

[162] Article 80 of Regulation (EU) 2018/1139 of the European Parliament and the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91

- providers of pan-European ATM/ANS
- providers "*that have their principal place of business located outside the territories for which Member States are responsible under the Chicago Convention and they are responsible for providing ATM/ANS in the airspace above the territory to which the Treaties apply*".

This may apply to the ADSPs as described in this study, at least for models 2 and 3 and would require further assessment.

In addition, Article 64 of the same Regulation acknowledges that a *"Member State may request the Agency* [EASA] *to carry out the tasks related to certification, oversight and enforcement*" and that a "*Member State may request another Member State to carry out the tasks related to certification, oversight and enforcement*".

Overall, such functions must be executed "*without prejudice to the rights and obligations of the Member States under the Chicago Convention*."[163]

F.3.3.4 Conclusions on the legal acceptability of decoupling considering certification / oversight issues

- Decoupling of ATM data service provision from 'core' air traffic services to private entities is allowed under the Chicago/ICAO regime, subject to respect for the principle of international State responsibility in national airspace.
- The 'European' regime (EASA and SES) is aligned with this Chicago/ICAO regime.[164] In addition, it allows more flexibility and differentiation with respect to the provision of ATM/ANS and the draft new Commission Regulation on performance and charging scheme explicitly allows submitting ATM data service provision to decoupling and market conditions.
- Certification / Oversight (supervision) functions are organised under the EASA Basic Regulation. The expected set-up of the ADSPs to be created under the proposals contained in the study *a priori* points to EASA as being the competent authority. However this will have to be confirmed through a proper examination once the set-up of ADSPs becomes clearer.

F.3.4 The ATM data services to be provided

F.3.4.1 Scoping the services to be provided by ADSPs and the certification topic

There is potentially a large scope of services that could be provided by the future ADSPs, whatever their model and legal set-up. The nature of these services is described in section 4.3.1.2 and in particular Table 5; further defintion of individual services is required.

[163] See, Art. 64 of Regulation 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency

[164] ATM measures of the SES "shall be without prejudice to Member States' sovereignty over their airspace and to the requirements … relating to the public order, public security and defence" (see Art. 1, para. 3 of Regulation 549/2004 as amended).

These data services are currently provided and used by the "legacy" ATSPs. With the recommendations of the study, their provision could be "decoupled" and entrusted to ADSPs set up in accordance of one of the three models envisaged (or even different ones that may not be explored yet, as these three models are not meant to be exhaustive, but simply indicative).

The figure below depicts the different air navigation services considered in the SES regime. The numbers in the boxes refer to the number of their definition in Article 2 of the framework Regulation No 549/2004 amended.

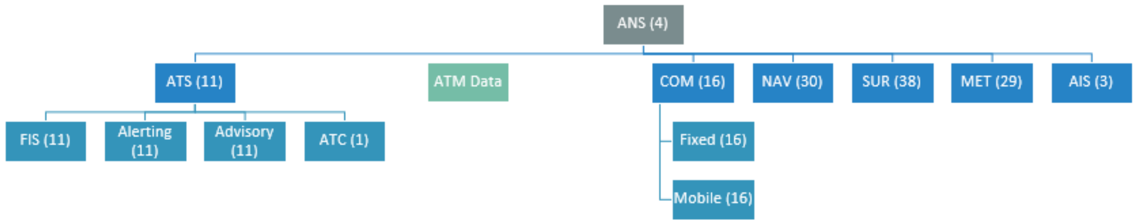

Figure 58: SES taxonomy for Air Navigation Services

Communication, Navigation, Surveillance, MET and Aeronautical Information Services are already identified as services potentially submitted to market conditions, and the certification requirements for providers are in Annexes PART-CNS, PART-MET and PART-AIS of the Common Requirements Regulation 2017/373.

In the context of this study, all or part of the data related to FIS, Alerting, Advisory and ATC, supporting Air Traffic Services, would also be provided to the ATSPs by the ADSPs. This explains the creation of the new "green box" on ATM data in Figure 58. This evolution is currently being anticipated in Article 35 of the draft implementing Regulation on performance and charging schemes that received a positive opinion from the Single Sky Committee on 17 December 2018.

This raises the issue of the certification of ADSPs. Whatever the model implemented, ADSPs will have to be certified in line with certification standards drawn up in the Common Requirements Regulation (EU) 2017/373 in order to be able to offer their services within the EU[165]. This Regulation currently contains Annexes describing the requirements for certification of ATS, C, N, S, MET, AIS and DAT services, but does not contain yet identification of ATM data services and a description of the requirements for certification.

To satisfy the obligation to secure certification of ADSPs the first task will be to identify and define precisely all the services possibly provided by ADSPs and identify the gaps with the existing regulatory framework. EASA should then, on this basis, be invited to develop the requirement for their certification, create a specific Annex of Regulation 2017/373 for this purpose and, as necessary, review and update the existing annexes of the Regulation, to avoid gaps or overlaps. It should be noted that an organisation certified as an ADSP could also provide the other ANS (ATS, CNS, AIS, MET) so long as they are also certified for those services. When doing this, EASA should also address and provide guidance or regulation on the issue of data access and ownership.

[165] Article 7 of the service provision Regulation (EC) No 550/2004 as amended.

F.3.4.2 Conclusions on identification of services and need for Common Requirements update

- Building on the on-going work in the SESAR programme and possibly accelerating the innovation lifecycle, the services to be provided by ADSPs need to be identified and defined (involving EASA and associating the industry / stakeholders);
- On such a basis EASA should develop the requirement for the certification of the provider of such services, create a specific Annex for this purpose and as necessary review and update the existing annexes of the Common Requirements Regulation 2017/373;
- In the study the establishment of ADSPs covers the notion of two new services, namely the "Integration services" to be provided by ADSPs and the "Geographically-fixed services" which will be an input to ADSPs. When reviewing the regulatory framework, it is recommended to acknowledge the existence and provide a definition of such services to ensure a common understanding and harmonised implementation across Europe.

F.3.5 Alliance building between ANSPs

Arrangements between ANSPs are welcomed in the SES regime and regulated in Article 10 of the Service Provision Regulation 550/2004 as amended. These arrangements currently focus on technical and operational matters and may be laid down in so called 'Letters of Agreement' concluded between ANSPs. Providers of air traffic services, including the various flight information services, alerting services, air traffic advisory services and meteorological services, must obtain approval of their arrangements from the Member States involved with cross-border service provision.

Currently, ANSPs in Europe are already building alliances as exemplified by Borealis Alliance, offering Free Route Airspace (FRA) in Northern Europe, COOPANS, sharing the same ATM system, and A6 consisting of now seven ANSPs focussing on SESAR development and deployment up to its execution (planning, governance, funding).

With the present study, alliances between ANSPs appear to go beyond the above technical arrangements as they also foresee potentially the creation of joint ventures for the production and provision of air traffic data and/or the joint purchase of air traffic data. Such alliances are not explicitly envisaged in the SES regime but that does not imply that they are not permitted. On the contrary, evolution towards decoupling of ancillary services, including ATM data service provision from core ANS services, is encouraged in principle.

However, it should be noted that such arrangements including 'alliances' may come under scrutiny of competition authorities, in particular if they go beyond mere technical cooperation, which is the principal goal of such alliances. The EU Court of Justice has indeed adopted a very broad interpretation of the application of the competition law articles to undertakings possessing special public service related privileges which interpretation may also affect the position of service providers envisaged in this study. This is addressed in more detail in F.3.6 below.

F.3.5.1 Conclusions on alliances between ANSPs

- The Chicago/ICAO regime does not regulate alliances between ANSPs. It proceeds from the 'silo' model without forbidding other models.
- The SES regime may have to be adapted to provide a more solid legal basis for the avenue of alliance building between ANSPs for the provision of ATM data services.
- Alliances between ANSPs and/or ADSPs may also be subject to the EU competition law regime (which is examined briefly in the next section).

F.3.6 Potential impact of EU competition rules on the three models

The three models proposed in the study are intended to support the introduction of market conditions for ADSPs, with nuances between the models. Depending on the model proposed, such move may imply issues of compatibility with WTO rules[166] and application of the EU competition regime. This is discussed briefly below.[167]

ATS-related activities are currently not subject to EU competition law.[168] The SES regime states that provision of ATS "*is connected with the exercise of the powers of public authorities*."[169] It should be noted from F.3.4.1 above that the data likely to be provided by ADSPs will at least partly support ATS provision.

In the same line, the EU Court of Justice has repeatedly stated that Eurocontrol is not an "undertaking" because its activities are connected to the exercise of public functions.[170] In its 1994 *SAT Fluggesellschaft mbH v Eurocontrol* Case, the Court of Justice held that "*taken as a whole, Eurocontrol's activities, by their nature, their aim and the rules to which they are subject, are connected with the exercise of powers relating to the control and supervision of air space which are typically those of a public authority. They are not of an economic nature justifying the application of the Treaty rules of competition*."[171].

However, attention must be drawn to the potential impact of such evolution. The *Aéroports de Paris* case[172] provides a vivid example of an activity - the operation of airports - being considered as an economic activity, while it has not been in the past: the multiplication of privately-owned entities, generating profit, made the Court change its position regarding the nature of the activities undertaken by airports. Furthermore, given the broad interpretation of the "undertaking" concept as

[166] Financial assistance to AU to buy new systems could be interpreted as cross-subsidisation of aircraft and parts manufacturers; financial assistance to ANSPs to buy new systems could be interpreted as cross-subsidisation of the ANS system manufacturers.

[167] See, Ch. Swaak, M. van der Woude, *Competition Law and Policy*, in, P. J. Kuijper, F. Amtenbrink, D. Curtin, B. De Witte, A. McDonnell, S. van den Bogaert (eds.), *The Law of the European Union*, Kluwer Law International, 2018, 1402 pp., pp. 715-778.

[168] ECJ, 19 January 1994, *SAT Fluggesellschaft / Eurocontrol*, Case C-364/92; ECJ, 26 March 2009, *Selex Sistemi Integrati / Commission*, Case C-113/07 P, ECR 2009, p. I-2207.

[169] See Recital 10 of Regulation 550/2004 as amended.

[170] See ECJ, 14 October 1976, *LTU / Eurocontrol*, *op. cit.*; ECJ, 14 July 1977, *Bavaria Fluggesellschaft and others / Eurocontrol*, *op. cit.*

[171] ECJ, 19 January 1994, *SAT Fluggesellschaft / Eurocontrol*, *op. cit.*, para. 30.

[172] CFI, 12 December 2000, *Aéroports de Paris / Commission*, Case T-128/98, ECR 2000, p. II-3929; ECJ, 24 October 2002, *Aéroports de Paris / Commission*, Case C-82/01 P, ECR 2002, p. I-9297.

explained by the Court of Justice in its *Höfner and Elser* Case,[173] an economic activity, even provided by a publicly-owned entity, will be subject to EU competition law, including state aid law.

The qualification of ADSPs as *undertakings* which are subject to EU competition law is, hence, to be addressed and assessed in relation to the *nature of the activity*, in this case service provision, rather than the form or the structure of the entities involved with the activities.

Since the aim is to subject ADSPs to market conditions (with nuances depending on the models), the services provided by these entities may be declared of an "economic nature", and this may trigger the application of EU competition law.

A detailed analysis of this issue could not be carried out within the time and scope allocated to this study, and thus remains to be done to establish whether and to what extent EU competition law may apply and what would be the consequences.

State aid law may also apply and this is addressed under F.4.3.5.1 on the incentive "Direct financial support from Member States".

Should it be concluded that competition law applies, a number of aspects may require further consideration in the context of the SES regulatory regime, including the following:

Scope for exemptions from provisions prohibiting collusive behaviour between undertakings

Article 101 of TFEU prohibits cartels and other collusive arrangements between "undertakings" which may affect trade between Member States and which have as their object or effect the prevention, restriction or distortion of competition within the internal market. The form and substance of alliances,[174] arrangements, or concerted practices in relation to ATM data service provision are, as yet, unknown. Such arrangements may, according to jurisprudence of the EU Court of Justice, include an isolated exchange of information between ADSPs and ANSPs. This jurisprudence illustrates the broad view which the EU Court of Justice adopts with respect to the scope of the EU competition regime.

If ANSPs are regarded as undertakings, or as 'public undertakings', they may potentially be exempted from the above prohibition on collusive behaviour where such behaviour is found to contribute "[…] *to promoting technical or economic progress, while allowing consumers a fair share of the resulting benefit, and which does not […] impose on the undertakings concerned restrictions which are not indispensable to the attainment of these objectives […].*"

The creation of joint ventures

Competition law also addresses the creation of joint ventures which may be at stake in Model 2. A joint venture may be regarded as a merger where two or more undertakings, including ANSPs - again, if regarded as 'undertakings' - each have the possibility of exercising 'joint control', in the sense of decisive influence over another undertaking, that is, the ADSP, in which case the creation of the joint venture must be notified and approved under the Merger Regulation (Regulation 139/2004).

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[173] ECJ, 23 April 1991, *Höfner and Elser / Macrotron*, Case C-41/90, ECR 1991, p. I-1979, para. 21: "the concept of an undertaking encompasses every entity engaged in an economic activity, regardless of the legal status of the entity and the way in which it is financed and, secondly, that employment procurement is an economic activity."

[174] See, section F.3.5.

Joint production and joint purchasing of data

In case of joint production and joint purchasing arrangements, benefits for the consumers in terms of lower costs must outweigh increased market power of the service providers (ANSPs and ADSPs).

Joint purchasing agreements are aimed at creating buying power implying lower prices or higher quality services for consumers. Such arrangements may also have to be assessed under Article 101 of TFEU, forbidding collusive conduct in the relevant market.[175]

Vertical arrangements between ANSPs and ADSPs

In case of vertical arrangements between ANSPs and ADSPs which may lead to economic efficiencies by facilitating better coordination, reduction of transaction and distributions costs, and the optimisation of investment levels, reference is made to the European Commission's Guidelines on Vertical Restraints below.

In *Model 3*, the vertical relationship of the ANSP with the ADSP is marked by the service of the ADSP as the input of the ANSP. Parties to such arrangements may have an incentive to prevent each other from imposing unreasonable limitations creating competition concerns. Commission Regulation 330/2010 providing a block exemption for specified vertical agreements and the Commission's Guidelines on Vertical Restraints[176] explaining principles for the assessment of vertical agreements pursuant to Article 101 of TFEU would potentially be of relevance in this respect.

F.3.6.1 Conclusions on applicability of competition rules

- Considering the uncertainty about the future structure and organisation of the ADSP market, both in an isolated fashion and in relation to the ANSP market, the transactions and arrangements among the different service providers can only be tested marginally against the EU competition law regime.
- There is in the ADS provision environment an acknowledged dimension of connection "*with the exercise of the powers of public authorities*". However, in light of the creation of market conditions for ADSP, the EU Treaty's rules on competition and the broad interpretation which the EU Court has given to the terms included in the competition law regime, there is a possibility that ADSPs will be, sooner or later, regarded as undertakings being subject to the EU competition law regime. The SES regime may have to be adapted to accommodate this evolutionary perspective.
- Further analysis will be necessary on such specific aspects in the context of an implementation programme.

[175] See, Communication from the Commission — Guidelines on the applicability of Article 101 of the Treaty on the Functioning of the European Union to horizontal co-operation agreements, *OJ* C 11, 14 January 2011, pp. 1-72.
[176] See, European Commission Guidelines on Vertical Restraints, *OJ* C 130, 19 May 2010, pp1-46.

F.3.7 Terms for acquisition of data

F.3.7.1 Fair compensation

According to the proposals, all data producers must make 'raw data' available to other certified ADSPs. Traditionally AIS providers have provided all relevant data *freely* to all interested parties, as a matter of 'public safety infrastructure principle'. The costs of the service have been absorbed in the route charges.

In accordance with Article 13 of the Service Provision Regulation (EC) No 550/2004, a discussion at European level would be useful to address and sort out the topic of access to and protection of operational data.

In all three models, ANSPs must obtain data from the - more or less - independent ADSPs against a 'fair compensation.' The term '*fair* compensation' appears to indicate that the price at which these data can be purchased is not determined by market forces, in a competitive environment. On the other hand, Model 3 is based on the creation of an environment "with competitive market entry."

The draft Commission Implementing Regulation laying down *a performance and charging scheme in the Single European Sky* allows that *"…. the provision of some or all of the terminal air navigation services, CNS, MET, AIS services or air traffic management ('ATM') data services provided in their charging zones …. is subject to market conditions*"[177]. Should these market conditions be applied, such States do not apply *a priori* set targets for cost-efficiency and other factors determining the cost price of the service in question.[178] In other words, a market price is a market price, and may therefore *a posteriori* be made subject to scrutiny of competition authorities.

At present it is understood that the starting point consists in the formulation of a regulation in which the terms for 'fair compensation' are laid down. In other words, pricing of data provision will be made subject to *a priori* regulation, as is the case globally with the charging scheme for ANSPs. That notion of 'fair compensation' has to be somehow matched with the market conditions envisaged in the above draft Regulation.

F.3.7.2 Interoperability of systems

In the current setting, "*Access to operational data must be granted to […] certified ANSPs*." Such data shall be used for operational purposes only. ANSPs must draw up standard conditions for access to their "relevant" operational data, which conditions must be approved by the competent authorities. So far, as they are not yet created, ADSPs are not targeted as separate entities to which interoperability standards should also apply. This should be addressed as the concept reaches maturity.

In order for the ADSPs to compete on a level playing field in a competitive market, the systems for data production and processing must be synchronised, and standards harmonised. The Interoperability Regulation (552/2004) provides a framework for interoperability but must be implemented for the purpose of setting up a market for ADSP. As far as this Regulation does not underpin this level playing field, existing data exchange standards can be considered for this purpose.

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[177] See, Art. 35, para. 1.
[178] See, Art. 35, para. 2.

F.3.7.3 Conclusions on pricing and interoperability

- For the time being it is concluded that norms for charging, or, in a broader sense, the design for a pricing mechanism require further analysis and may have to be adapted in order to support the timely implementation of the proposed architecture.
- On interoperability, initial appropriate standards are in place and will be further developed to secure smooth processing of data between providers and beneficiaries.

F.3.8 Compensation of damages in light of civil liability

As a corollary of the principle that the provision of ATS remains a sovereign function of the State, liability for the compensation of damages caused by the failure of such service provision may be attached to that same State.[179]

The ANSP availing itself of the services of an ADSP may require specific insurance for the compensation of damages caused by data provision. This ANSP must be able to define its own requirements in respect of financial exposure, which may be different from those of the national State of the ADSP.

Currently, liability of ANSPs is primarily governed by the national laws of the State in whose territory the services are provided, unless specific arrangements are concluded between the States involved. Most national legislations do not encompass provisions on liability for ANSPs or ADSPs.

Other States apply the concept of the ‘subsidiary liability of the State’ pursuant to which the ANSP or ADSP is liable in the first instance. However, the territorial State holds a subsidiary liability for the compensation of damages exceeding the insurance coverage or financial capacity of the ANSPs or ADSPs.

An international convention on liability of ANSPs does not exist. Thus, instruments which address liability should address topics concerning notably (but not exclusively):

- the national legislation of the territorial State;
- the licence of the ANSPs and ADSPs, with special reference to insurance coverage;
- agreements between States in case of cross-border service provision;
- arrangements between ADSPs when they cooperate with respect to service provision in relation to an alliance of ANSPs.

EU Member States will pay special attention to this question of liability as the primary State responsibility for ATM/ANS tasks may be, but does not necessarily have to be, linked to primary State liability. The word ‘may’ is used in light of the performance of ANSPs and ADSPs as a sovereign task, implying that States may rely on immunity of jurisdiction. Whether this is the case must be looked at on a State by State basis.

As a corollary, agreements between States in the context of FABs or otherwise, which include the regulation of liability, are only binding for the States parties to the agreement, and the ANSPs and

[179] See the “*Űberlingen* case”, decision of the District Court of Konstanz, Germany, (Fourth Chamber) of 27 July 2006 in a case brought by Bashkirian Airlines against the Republic of Germany (Case Number 4 O 234/05 H).

ADSPs which are subject to the terms of such agreements. Such provisions on liability cannot be opposed to other, including European, States which are not a party to these agreements, unless and until a European regulation on liability for the compensation of damage caused by service provision in the ATM/ANS is developed and come into force.

F.3.8.1 Conclusion on liability

The question of liability requires special attention which must primarily come from the State in which the data services are provided, hence, the territorial State. Various legal possibilities have been presented for addressing this question.

F.3.9 Additional topics

In addition, this legal scrutiny has allowed identification of further points requiring examination, which include but may not be limited to:

- *Accident and incident investigation* in which data collection occupies a special place. Under Annex 13 of ICAO in conjunction with EU Regulation 996/2010 data coming from Flight Data Recorders (FDR) and Cockpit Voice Recorders (CVR) must be available for the Bureau which is responsible for the investigation of the accident. However, the preservation of these data for the - exclusive - purpose of accident investigation and the privacy aspects, which are related to it, are currently examined, among others, by the European Commission. Attention should also be paid to the accessibility of other data than those which are recorded in FDRs and CVRs for the said Bureau, and, possibly, other public authorities.
- *Intellectual Property Rights* (IPR), "especially when developed in the context of public funding"[180] pertains to data ownership and data collection. When data collection gives rise to monopoly positions in the ADSP market, these may result in an examination of the dominant position of such data owners in the ADSP market, and the potential abuse thereof, in light of Art. 102 TFEU.
- *Data storage:* Information is not sufficiently available to address the question of regulating this topic. Individual ANSPs including ADSPs must establish "standard conditions of access to their operational data" which means that there is no EU based guidance on data protection.
- Other topics may concern the protection of data against cyber security, the use of data by military authorities, and civil-military coordination.

F.4 Targeted incentives for early movers

F.4.1 Introduction

To deliver in a full and timely manner the benefits expected from the future airspace architecture, effective ways to incentivise ANSPs and AUs (airspace users) to embrace the new technological solutions through early investment may be needed.

For the time being, under the existing legislation, and even though investment projects can benefit – and are actually benefitting - from EU funding in particular for the implementation of common projects, ANSPs are not effectively encouraged to invest early in new technologies. In fact, reports

[180] See, I. A. Laszlo, "European Air Traffic Management from a New Perspective: Competition Concerns in the Single European Sky", *op. cit.*, pp. 347, 348 and 355

from the Performance Review Body identify a systematic under-investment (difference between CAPEX planned in the performance plans and actual CAPEX) by about 25%[181] (also acknowledging that there are large differences between ANSPs). More recent information collected does not indicate any substantial improvement of this situation.

On their side airlines / airspace users should, in theory, be incentivised to support a better usage of airspace, as:

- delays imply additional costs (e.g. Regulation (EC) 261/2004 on flight compensation; working schedules of flying crew);
- longer routes result in higher fuel consumption and CO_2 emissions;
- increasing/fluctuating fuel price.

However, these indirect incentives appear to be insufficient, since charges supported for air navigation services are unavoidable operational costs for the airlines, sometimes higher than 10%.[182] ATM charges amount, on average, to EUR 900 per flight, adding up to about EUR 9 billion per year for airlines.[183] Moreover, the fact that airlines sometimes deliberately choose to fly longer routes, across Member States with lower charges (as there are wide differences between national en route unit rates) – leading to higher CO_2 emissions and possibly hampering an efficient usage of the airspace available – demonstrates that, for airspace users, the benefits of avoiding flying in certain costly areas exceed the losses incurred by flying longer routes.

Furthermore no modulation of charges for early equipage of aircraft is implemented even though such possibility is explicitly foreseen in Article 16 (2) of the Charging Regulation (EU) No 391/2013.

Such lack of powerful incentives for ANSPs and airspace users to invest early into technology and the lack of incentives for airspace users to fly network and capacity-optimal routes may slow down or even jeopardise the delivery of the recommendations of the airspace architecture study and their related benefits.

Hence, the proposal for the future architecture of the European airspace lists several potential incentives directed at both airspace users and service providers. The proposal suggests most notably to offer lower en-route charges for AU having adopted SESAR related technologies and/or preferential ATM services. Additionally, Section 5.3 of the proposal lists several measures which could potentially constitute incentives for airspace users and/or service providers. The legal aspects of these potential incentives are addressed below.

[181] PRB RP2 Annual Monitoring Report 2015- Vol.3 CAPEX – version 2.0, Paragraph 2.2

[182] L. Castelli, T. Bolic, S. Costanzo, D. Rigonat, E. Marcotte, G. Tanner, "Modulation of *en route* charges to redistribute traffic in the European airspace", December 2015, at: https://www.sesarju.eu/sites/default/files/documents/sid/2015/SIDs_2015_paper_35.pdf, 8 pp., p. 1.

[183] European Court of Auditors, Single European Sky: a changed culture but not a single sky, Special Report No. 18, 2017, 71 pp., p. 12.

F.4.2 Incentives for airspace users

F.4.2.1 Modulation of / lower route charges for airspace users having equipped with SESAR technologies

Modulation of charges is explicitly foreseen in Article 16 (2) of the Charging Regulation (EU) No 391/2013, but on a voluntary basis at the discretion of States or FABs, and has not been implemented so far. The costs and complexity of this scheme have been perceived by stakeholders as exceeding the benefits that can be generated.

Innovative ways of implementing such a scheme could still be explored, e.g. using EU funding to offer lower charges to equipped aircraft. This would not affect ANSP revenue or change the unit rates, and would largely facilitate the administration of the scheme. Another approach could be to implement a "pay per service used" scheme.

In any case, lower charges should not be applied only to European registered airlines, as it would contradict the non-discrimination principle set forth in Article 15 of the Chicago Convention. On the other hand the non-discrimination principle does not forbid differential charges. Under general international trade law, what the non-discrimination principle prohibits is dissimilar treatment in similar situation, while differentiation in conduct that can be objectively and reasonably justified are admissible. This approach is, in essence, the one expressed by ICAO's guidance materials, most notably its policies on charges[184]. Several high-level principles are however identified in order to avoid the potential negative effects of differential charges:

- charges should not be imposed in such a way as to discourage the use of facilities and services necessary for safety or the introduction of new aids and techniques.[185]
- the system of charges must not discriminate between foreign users and those having the nationality of the State or States responsible for providing the air navigation services and engaged in similar international operations.[186] Hence, "all categories of users meeting the same criteria and offering the same or similar air services should be treated equally".[187]
- differential charges shall be established in full transparency, regarding their existence and rationale as well as regarding their purpose and criteria.[188]
- non-cross-subsidisation, as "the costs associated with such differential charges should not be allocated to users not benefiting from them".[189]
- gradual implementation of the changes in charging systems to avoid undue disruptions to users.[190]
- time-limitation, as "Charges offered for the purpose of attracting or retaining new air services should only be offered on a temporary basis".[191] The scope of this principle is broadened in ICAO's Manual on Air Navigation Services Economics, which states that:"This principle relates to the amount of time that an ANSP may provide particular categories of

[184] ICAO's Policies on Charges for Airports and Air Navigation Services, 9th edition, 2012, ICAO doc. 9082.
[185] ICAO's Policies on Charges for Airports and Air Navigation Services, 9th edition, 2012, ICAO doc. 9082 Section III, para. 6, ii).
[186] ICAO's Policies on Charges for Airports and Air Navigation Services, 9th edition, 2012, ICAO doc. 9082 Section III, para. 6, iv).
[187] ICAO's Manual on Air Navigation Services Economics, 5th edition, 2013, ICAO doc. 9161, p. 5-37.
[188] ICAO's Policies on Charges for Airports and Air Navigation Services, *op. cit.*, Section III, para. 6, v).
[189] ICAO's Policies on Charges for Airports and Air Navigation Services, *op. cit.*, Section III, para. 6, v).
[190] ICAO's Policies on Charges for Airports and Air Navigation Services, *op. cit.*, Section III, para. 6, vii).
[191] ICAO's Policies on Charges for Airports and Air Navigation Services, *op. cit.*, Section III, para. 6, v)

users with *preferential treatment to encourage the introduction of new technologies* (e.g. early equipage). Since the air services receiving preferential treatment are ultimately expected to become profitable, such schemes should be offered only on a temporary basis.*"*[192]

- With these safeguards, ICAO principles support incentive measures directed at AUs, as long as they satisfy the objectivity and reasonability criteria, most notably if, notwithstanding the investment effort, the costs of ANS are significantly reduced in the future thanks to new (SESAR) technologies: "*Experience has shown that users tend to defer as much investment in aircraft equipment as possible, preferring short term savings (deferring an investment) to less certain collective benefits that are dependent on the synchronisation of ground and on-board equipment investments. Therefore, incentives for early adoption of on-board equipment may help support the implementation of new technologies and, over time, could contribute to a better adjustment of ATM capacity to the needs of the air transport industry*".[193] Such incentives are already applied under ICAO, e.g. in Canada, which implements reduced charges for communications operated through Data Link (18.5$) in comparison to voice communications (48.78$).[194]

Conclusions:

- Under ICAO and SES regimes, lower route charges can be adopted to provide incentives to early movers, provided that they comply with the general principles set out in ICAO, which is the case.
- The practicalities of such a scheme should however be reviewed to overcome the current reluctance of almost all stakeholders under the existing provisions, e.g. through using EU funding to offer lower charges to equipped aircraft or to implement a "pay per service used" scheme.

F.4.2.2 Preferential ATM services to airspace users equipped with SESAR technologies

The Study proposes to revive the "Best Equipped Best Served" (BEBS) concept[195]: "*BEBS means that the airspace users that have reached higher capability levels would benefit from a more efficient operational environment. BEBS should be seen as an operational incentive principle and should complement the FCFS principle*"[196]. This concept is not contained in the SES legislation, so it should be assessed against the ICAO provisions.

[192] ICAO, Manual on Air Navigation Services Economics, *op. cit.*, p. 5-37.
[193] ICAO, Manual on Air Navigation Services Economics, *op. cit.*, p. 5-38.
[194] NavCanada, Notice of Revised Service Charges, May 2018, at: http://www.navcanada.ca/EN/products-and-services/Pages/Notice%20-%20EN%20-%20Posted%202018.05.28.pdf.
[195] *See* ICAO Conference Papers, ATM Performance and the "Best Efficiency Best Served" (BEBS) Principle (Presented by the Presidency of the European Union on behalf of the European Union and its Member States; by the other Member States of the European Civil Aviation Conference; and by the Member States of Eurocontrol), 3/10/2012, AN-Conf/12-WP/58, 4 pp., p. 1.
[196] SESAR, Meeting ADB(M)019, 17 November 2011, at : https://www.sesarju.eu/sites/default/files/documents/adb/2011/ADB_M_019-Final_MoM-ADB_SIGNED.pdf, 16 pp., p. 10.

The management of air traffic flows currently and usually relies on the notion of "First Come First Served"[197] (FCFS) meaning that: "*different airspace users are in normal circumstances handled without discrimination and that priority is given to the aircraft that is first using a certain resource (runway, airspace)*"[198]. Differentiation of ATM services to AUs must be examined in light of Article 28 of the Chicago Convention. Accordingly, States must, "*as* [they] *may find it practicable"*, provide ATM, MET, and AIS services. Since Article 15 Chicago Convention prescribes that "*uniform conditions shall apply to the use, by aircraft of every contracting State, of all air navigation facilities*", one could infer that the provision of ANS (as per Article 28 Chicago Convention) should also respect the non-discrimination principle (as per Article 15 Chicago Convention). However, as indicated in its heading, Article 15 Chicago Convention covers "Airport and similar charges". Hence, its scope is limited to charges and the non-discrimination principle it enshrines is, arguably, not extended to the provisions of Article 28 Chicago Convention.

In any case, if a different interpretation were to be adopted, *i.e.* that non-discrimination also applies to Article 28 Chicago Convention, it would not forbid *differential*, rather than *preferential*, services to be provided. Drawing from the interpretation of the non-discrimination principle described above, a differential treatment of dissimilar situations would be allowed if:

- it does not, directly or indirectly; introduce differential treatment on the basis of the nationality of the AUs (registration).
- it does not discourage the use of facilities and services necessary for safety (the introduction of new techniques being the purpose of the Study's proposals), as Article 28, para. 1 of the Chicago Convention obliges the contracting States to provide ATM services to aircraft engaged in international operations, and maintain acceptable levels of safety[199]. Hence, both traditional (i.e. based on older technologies) and new services (i.e. based on SESAR technologies) must be offered simultaneously to AUs, which could possibly reduce cost rationalisation at ANSPs level.
- differentiated services are established in full transparency and based on sound, objective and reasonable criteria. The technical aspects appear to be the only justification legally admissible for the differential treatment.
- they do not unduly favour AUs equipped with SESAR technologies, for instance by forcing other AUs to fly significantly longer routes even when the shorter ones are not congested.

Hence, it appears that the non-discrimination principle laid down in Article 15 Chicago Convention should not be extended to Article 28 Chicago Convention. If an alternative interpretation is adopted, differential treatment on the basis of technical, equipment related, criteria would in any case be permissible.

The main obstacle to the introduction of preferential ATM services to AUs equipped with SESAR technologies, putting aside the additional administrative burden, can be found in Annex 11 to the Chicago Convention. Different levels of services can be offered, depending on the need for air traffic services[200], but the dividing line is generally the portion of airspace,[201] thus its class,[202] rather than

[197] SESAR, Meeting ADB(M)019, 17 November 2011, at : https://www.sesarju.eu/sites/default/files/documents/adb/2011/ADB_M_019-Final_MoM-ADB_SIGNED.pdf, 16 pp., p. 10.
[198] SESAR, Meeting ADB(M)019, 17 November 2011, at : https://www.sesarju.eu/sites/default/files/documents/adb/2011/ADB_M_019-Final_MoM-ADB_SIGNED.pdf, 16 pp., p. 10.
[199] *See also*, Art. 2.1.1. of ICAO, Procedures for Air Navigation Services – Air Traffic Management, 16th edition, 2016, ICAO doc. 4444.
[200] Art. 2.4.1 of Annex 11 to the Chicago Convention.

the technology being used (radio and data link, for instance, are subject to equivalent rules and ACAS equipment are irrelevant when defining the needs for air traffic services).[203]

It is not disputed that access to aerodromes and services is sometimes differentiated on aircraft equipment (minimum navigation performance specification (MNPS) or reduced vertical separation minimum (RVSM))[204], but subject to approval in order to ensure safety. Furthermore, ICAO's contracting parties do not seem to be opposed to service priority as reflected by Recommendation 6/2 adopted during the 12th Air Navigation Conference in 2012, which encouraged ICAO to: "*Develop an appropriate set of operational and economic incentive principles to allow early benefits of new technologies and procedures, as described in the aviation system block upgrade modules, to support operational improvements, while maximising safety, capacity and overall system efficiency*."

To date the Best Equipped Best Served notion has not been endorsed at the international level[205] and is not yet reflected in either Annex 11 or ICAO Doc. 4444. Evolutions may flow from the progressive implementation of the performance-based approach for ANS,[206] also embraced at the European level.[207]

Conclusions:

- The Chicago Convention does not appear to forbid differential (and not preferential) services being offered to AUs, as long as there is no discrimination among users on the basis of nationality and provided that the differentiated services are based on objective, transparent and technical criteria. The requirement to keep on providing standard, conventional, services to other AUs would possibly delay the benefits of the cost reduction that would be achieved with SESAR technologies.
- On the other hand no provision, within Annex 11 of the Chicago Convention or within ICAO Doc. 4444, foresees the possibility to offer preferential service depending on SESAR related equipment, as the different levels of services depend on the class of airspace. Furthermore, the BEBS notion has still not been translated into the relevant instruments.[208] Thus, the legal validity of preferential services would probably necessitate a further in-depth assessment.

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[201] Art. 2.5.1 of Annex 11 to the Chicago Convention.
[202] Art. 2.6.1 of Annex 11 to the Chicago Convention.
[203] Art. 2.4.2 of Annex 11 to the Chicago Convention: "The carriage of airborne collision avoidance systems (ACAS) by aircraft in a given area shall not be a factor in determining the need for air traffic services in that area."
[204] ICAO, ATM Performance and the "Best Efficiency Best Served" (BEBS) Principle (Presented by the Presidency of the European Union on behalf of the European Union and its Member States ; by the other Member States of the European Civil Aviation Conference ; and by the Member States of Eurocontrol), *op. cit.*, p. 2.
[205] ICAO Working Paper, Implementing ASBUs for performance improvement, 26 September 2018, AN-Conf/13-WP/165, 3 pp., p. 3.
[206] ICAO, 2016-2030 Global Air Navigation Plan (GANP), 5th edition, 2016, ICAO doc. 9750-AN/973.
[207] Commission Implementing Regulation (EU) 2018/1048 of 18 July 2018 laying down airspace usage requirements and operating procedures concerning performance-based navigation, *OJ* L 189, 26 July 2018, pp. 3-8 ; Commission Implementing Regulation (EU) 2017/373 of 1 March 2017 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight, repealing Regulation (EC) 482/2008, Implementing Regulations (EU) 1034/2011, (EU) 1035/2011 and (EU) 2016/1377 and amending Regulation (EU) 677/2011, *OJ* L 62, 8 March 2017, pp. 1-126; Regulation (EC) 1070/2009 of the European Parliament and of the Council of 21 October 2009 amending Regulations (EC) 549/2004, (EC) 550/2004, (EC) 551/2004 and (EC) 552/2004 in order to improve the performance and sustainability of the European aviation system, *OJ* L 300, 14 November 2009, pp. 34-50.
[208] ICAO Working Paper, Implementing ASBUs for performance improvement, 26 September 2018, AN-Conf/13-WP/165, 3 pp., p. 3.

F.4.3 Incentives for service providers

F.4.3.1 Allowing a profit margin to be made for 1-on-1 agreements of provision of remote ATS capacity

According to ICAO's policy on Charges for Airports and Air Navigation Services: "*Air navigation services may produce sufficient revenues to exceed all direct and indirect operating costs and so provide for a reasonable return on assets (before tax and cost of capital) to secure efficient financing for the purpose of investing in new or enhanced air navigation services infrastructure.*"[209]

This is echoed in Recital 25 and Article 15, para. 3, c) of Regulation 550/2004: "Air navigation services may *produce sufficient revenues to provide for a reasonable return on assets* to contribute towards necessary capital improvements."

Article 10 of Regulation 550/2004 allows ANSPs to avail themselves of the services of other service providers that have been certified in the EU.

From the combined reading of these provisions, the existing legal framework does not seem to prevent reasonable profit deriving from ANS, be it from remote ATS provision, even if the existing legal instruments are silent in this respect.

Conclusion:

The existing legal framework does not prevent reasonable profit deriving from air navigation services provision.

F.4.3.2 Rewarding the achievement of specific KPIs

Bonuses for the achievement of Key Performance Indicators are already allowed by Article 15, para. 1 of Implementing Regulation 391/2013.[210] The KPIs triggering the bonuses (or penalties) are linked to safety, capacity, environment and cost-efficiency, in accordance with Article 12 and Annex I of Implementing Regulation 390/2013. As the main purpose of the Study's proposal is to tackle and anticipate both future capacity constraints and achieve better cost-efficiency, the existing legal framework does not impede rewarding the achievement of specific KPIs related to the deployment of SESAR technologies.

Arguably, it is even possible to consider that the existing law already provides for incentives to implement SESAR technologies. Indeed, the capacity-related KPIs for *en route* ATFM delay include average minutes delay. Yet, one of the Study's ambitions is to mitigate and reduce ATM-related delays. Alternatively, if the investment costs are included in the actual costs *via* restructuring costs (see paragraph F.4.3.3. below), this would increase the unit rates and, thus, guarantee the equilibrium of the system of bonuses/penalties related to cost-efficiency KPIs, with higher reference costs.

[209] ICAO's Policies on Charges for Airports and Air Navigation Services, *op. cit.*, p. III-2, Section III, para. 3, vi).

[210] See also the discussion in Annex F.4.3.3

Conclusions:

- The existing legal framework allows for the allocation of bonuses (and also penalties) for reaching / not reaching performance targets for the KPIs contained in the performance scheme.
- If more ambitious solutions were to be implemented (e.g. new KPIs), this would require a regulatory update.

F.4.3.3 Allowing faster cost depreciation and decommissioning of legacy assets

The proposal to allow faster depreciation and decommissioning of legacy assets aims at favouring the transition from old technologies to new ones, by including faster and higher depreciation costs for existing systems, as they would be phased out earlier than expected when they were bought/installed/started.

Article 7, paragraph 2 of Implementing Regulation 391/2013 establishes that "*Fixed assets shall be depreciated in accordance with their expected operating life, using the straight-line method applied to the costs of the assets being depreciated. Historic or current cost accounting may be applied for the calculation of the depreciation.*" Hence, the SES regime does not seem to allow faster depreciation in case of early/provoked obsolescence.

On the other hand, Article 2.3.3.4. of Eurocontrol's Charging Principles does provide for the possibility to tackle this issue as: "*When it becomes apparent that the operating life of an asset being depreciated will be shorter than was anticipated when the original depreciation schedule was drawn up, one of the following two methods shall be adopted:*

- The net book value of the asset may be written off over the remaining years of the revised operating life;

- The precise amount of the residual value less any proceeds from its disposal may be added in full, in the financial year in which it occurs, to the depreciation charged in that year."[211]

Therefore, in case of sufficient willingness, there would be no obstacle to changing Implementing Regulation 391/2013 in the future to reflect this Eurocontrol provision. It would, moreover, guarantee that EU Member States are not bound by conflicting international obligations and reinforce legal certainty.

In addition, Regulations 390/2013 and 391/2013 allow Member States to recover "restructuring costs", which are: "*one-time costs incurred by air navigation service providers in the process of restructuring by way of introducing new technologies and procedures and associate business models to stimulate integrated service provision where the Member State wishes to recover the costs in one or more reference periods. They may include costs incurred in compensating […] writing off assets and/or acquiring strategic participations in other air navigation service providers*"[212].

[211] Art. 2.3.3.4. of Eurocontrol, Principles for Establishing the Cost-Base for en route Charges and the Calculation of the Unit Rates.
[212] Article 2, para. 18 of Regulation 390/2013.

Such restructuring costs can be taken into account, for recovery, when establishing the determined costs for *en route* cost-efficiency performance targets at local level, during both the reference period and the next one.[213] Under Regulation 391/2013, the calculation of actual costs may include such restructuring costs "*Incurred in reference periods precedent to the reference period(s) of recovery and subject to a business case demonstrating a net benefit to users over time*" [214].

Therefore Regulation 391/2013, while not allowing explicitly faster cost depreciation, offers the possibility to recover restructuring costs, which provides for the same effects as intended by the Study. Furthermore, the decommissioning is explicitly contemplated. The inclusion of restructuring costs into the calculation of actual costs is subject to prior authorisation from the European Commission, who assesses the net benefit for users over time. Given the objectives pursued by the SES Regulations and SESAR, such condition can be, if not presumed, at least demonstrated when Member States are actually implementing SESAR technologies at ANSP level.

Conclusion:

Allowing faster cost depreciation and decommissioning of legacy assets appears to be possible under the existing regulatory framework, either through integration into the Charging Regulation of the relevant provision of the Eurocontrol Principles for establishing the route charges, or through the implementation of the provisions underpinning the concept of "restructuring costs".

F.4.3.4 European guarantees for first movers

For the time being the option of offering European guarantees for first movers is not foreseen within the Single European Sky legal framework. However, Article 309 TFEU provides that the European Investment Bank shall grant loans and give guarantees to finance projects of common interest to several Member States and projects "*for modernising or converting undertakings or for developing fresh activities called for by the establishment or functioning of the internal market*."

Conclusions:

The implementation of the Single European Sky, being both a project of common interest and a project necessary for the well-functioning of the air transport internal market in the future, would realistically qualify to loans and/or guarantees granted by the EIB.

F.4.3.5 Direct financial support mechanism to new ADSPs

F.4.3.5.1 Direct financial support from Member States

The legal implications of direct financial support from Member States will depend on the qualification, or not, of ADSPs as "undertakings".

[213] Annex II, para. 3.1., d) of Regulation 390/2013.
[214] Article 7, para. 4 of Regulation 391/2013.

If ADSPs were to be qualified as “undertakings” carrying out economic activities, financial incentives adopted at national level, such as tax exemptions, would come under state aid law scrutiny, including the prior notification obligation. However, the possibility that such financial support would be declared compatible with EU Law under Article 107, para 3, b) TFEU could be explored, as aid provided by Member States would allegedly constitute “*aid to promote the execution of an important project of common European interest*”.

In the alternative, *i.e.* ADSPs not being qualified as undertakings carrying out economic activities, state aid law would not come into play and, thus, investments made by Member States would be exempted from the application of Article 107 TFEU. The most plausible situation would be, however, that ADSPs would not be qualified as undertakings in the short-term period, in accordance with the *SAT Fluggesellschaft* and *Selex Sistemi Integrati* Cases, before being subject to competition law in the future if they effectively act under market conditions.

F.4.3.5.2 Direct financial support from the European Union

SESAR-related investments can benefit from trans-European transport network (TEN-T) funding, since Regulation 1315/2013[215] explicitly identifies air navigation systems, including the SESAR technologies, among the infrastructure components eligible[216] and states that priority shall be given to “supporting the implementation of the Single European Sky and of air traffic management systems, in particular those deploying the SESAR system.”[217]

Conclusions:

- Direct financial support from the European Union to ADSPs would be possible.
- Direct financial support from Member States may raise legal issues, in case where state aid law would be found applicable. This deserves further study.

F.4.3.5.3 Exempting SESAR investments costs from the performance scheme, subject to appropriate controls being put in place

The proposal to make SESAR investments costs exempt from the performance scheme aims at reducing the impact of investment on the cost-efficiency KPI, in order not to penalise early movers.

Such proposal is contained in Article 28 (3) (a) of the draft new Regulation on performance and charging, which received a positive opinion from the Single Sky Committee on 17 December 2018, and, subject to the final and formal adoption of this Regulation by the Commission, would therefore not cause any legal difficulty.

[215] Regulation (EU) 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision 661/2010/EU, *OJ* L 348, 20 December 2013, pp. 1-128.
[216] Art. 24 of Regulation (EU) 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision 661/2010/EU, *OJ* L 348, 20 December 2013, pp. 1-128.
[217] Art. 26, b) of Regulation (EU) 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision 661/2010/EU, *OJ* L 348, 20 December 2013, pp. 1-128.

It is however noted that this draft is very generic and e.g. does not even restrict the exemption to SESAR-related investments. With such drafting, any investment cost can potentially be exempted from the cost-efficiency target of the performance scheme.

Such exemption possibility may lead to possible abuse if not properly overseen and accompanied by powerful control mechanisms aiming at genuinely identifying the investment and checking the effectiveness of their link with the SESAR programme and, within the scope of the present Annex, the implementation of the Study.

This is a highly recommended prerequisite to an efficient implementation of this mechanism. .

Conclusions:

- The planned legal framework plans to allow exempting investments costs from the cost-efficiency target of the performance scheme.
- However this should be accompanied by proper oversight and control mechanisms.

Annex G Impact Assessment

G.1 Purpose

This annex presents the methodology and results of the impact assessment performed to estimate net benefits of the full transition strategy. It also includes sensitivity analysis to cover the three main uncertainty areas: delay reduction estimations, future traffic forecast and estimating the size of investment needs.

G.2 Methodology and key assumptions

The high-level impact assessment is based on a conservative top-down approach relying on simulation results from the Network Manager, SESAR Validation Targets as well as the overall SESAR performance ambition defined in the European ATM Master Plan to ensure the highest level of consistency.

Results should be considered as rough order of magnitude estimations and will need further refinement and validation in the future as investment commitments are realised. The key assumptions made for the impact assessment are:

- **Traffic forecast**: STATFOR regulated growth scenario[218] in alignment with the traffic forecast used for the Master Plan
- **Average fleet size** in 2017 and 2035: 13 600 and 22 500[219]
- Average **cost** of one delay minute: EUR 70[220]
- Number of **sectors**: 690[221]
- Number of **ACCs**: 65[222]
- Future number of **ADSPs**: 10[223]
- Number of **ANSPs**: 25[224]
- **Discount rates**: 7,3%[225]
- Average **fuel burn** per nautical mile (NM) of flight: 11 kg[226]
- **Price of fuel** per kg: EUR 0.31 [227]

[218] Available at: https://www.eurocontrol.int/sites/default/files/content/documents/official-documents/reports/challenges-of-growth-2018.pdf

[219] Eurocontrol estimates. Between 2017 and 2035, a linearly growth rate has been applied.

[220] Source: Standard Inputs for Eurocontrol Cost-Benefit Analyses – Edition January 2018

[221] Source: SJU estimate considering current number of sectors (719 in 2019 according to Eurocontrol Cost-Benefit Analyses – Edition January 2018) and ideal number of sectors from NM simulations

[222] The Performance Review Commission of Eurocontrol uses the number of 62 ACCs to cover the Eurocontrol membership. As this membership is smaller than ECAC area, a proxy of 65 is used for the purpose of this study.

[223] Source: SJU estimate

[224] Currently number of ANSP area is 38 (Standard Inputs for Eurocontrol Cost-Benefit Analyses – Edition January 2018), however we take as hypothesis that not all ANSPs will be concerned by changes proposed.

[225] Source: SJU estimates used for European ATM Master Plan 2019 Edition

[226] Source: Standard Inputs for Eurocontrol Cost-Benefit Analyses – Edition January 2018

G.3 Benefits

The table below presents the outcome of the high-level network performance impact assessment covering the proposed target architecture and associated transition strategy for the following SES key performance areas (KPA): capacity, environment, cost efficiency and safety at the 2035 horizon.

KPA	Performance impact (order of magnitude)
Capacity	Network is able to accommodate 15,7 million flights (increase of 50% in Network throughput compared to 2017) with delays below or at the level of the agreed SES target (max 0,5 min per flight distributed across all flights)
Environment	Between 240 and 450 kg of CO_2 saved on average per flight due to optimisation of trajectories
Cost Efficiency	Between EUR 57-73 saved per flight due to ANS productivity gains
Safety	All simulations have been done against controller workload and indicate that the same safety levels can be maintained

It is important to note that simulation results taken in isolation show an even more promising potential network performance impact where different aspects of the proposed target architecture where assessed as illustrated below and further detailed in Annex D. For example, zooming in on the KPA for capacity the increase in performance is presented in Figure 1 below. The middle column corresponds to 2030 and is based on the introduction of ECAC wide cross-border Free Route Airspace (FRA), optimised airspace re-reconfiguration and operational harmonisation including timely deployment of the Pilot Common Project. The right column corresponds to 2035 and includes additional SESAR Solutions that addresses both capacity and system resilience and scalability.

[227] Source: Standard Inputs for Eurocontrol Cost-Benefit Analyses – Edition January 2018

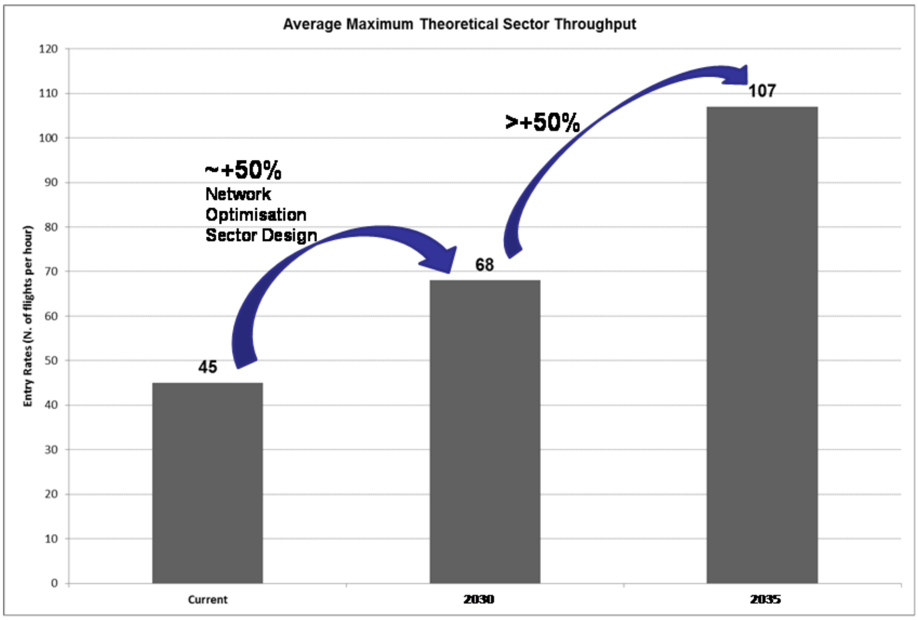

Figure 59 Average maximum theoretical sector throughput based on simulations

Last it is important to note that the insights generated in the study alone do not constitute a sound enough basis to call for an update of the SES High Level goals. It should be noted however that it would be valuable to consider the creation of a specific KPA targeting resilience in future SES Policy orientations.

A high-level economic estimation of the network performance impact of the targeted architecture and associated transition strategy was performed for three of the SES KPAs that could be monetised (capacity, environment and cost efficiency). The key results are illustrated in Figure 60 below.

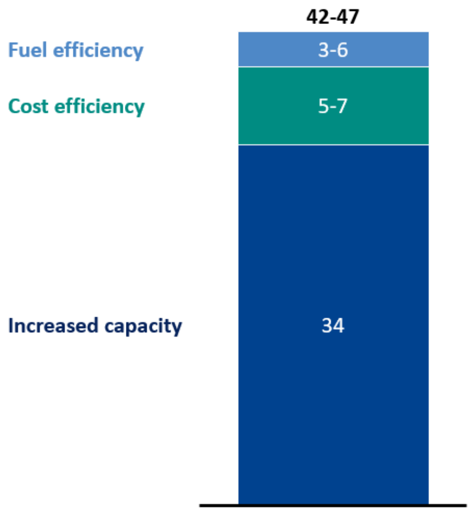

Figure 60. Accumulated benefits per source of efficiency for the period 2019-2035 (in EUR billion)[228]

[228] Source: SESAR JU, 2018

G.3.1 Capacity

Capacity has been addressed through the reduction of delays as estimated in the Master Plan and additional reduction linked to the ability to provide dynamic delegation of ATS and the capacity-on-demand service.

- Gains brought by the SESAR Solutions combined with airspace re-organisation, have been estimated by using the performance ambitions of the Master Plan. It has been considered that the optimal deployment of SESAR solutions in an optimised airspace organisation brings 60% of the delay reductions estimated for the entire Master Plan (which includes more than en-route improvements).

This would bring around **438 million of delay minutes saved** between 2019 and 2035 (from which 60 million minutes are saved in 2035).

- It is assumed that the additional resilience brought by the target architecture would enable the reductions of delays caused by staffing, disruptions, planned events, and weather. These delays impact only a certain percentage of flights. For these concerned flights the delay has been estimated by using the most recent data on total en-route delays for each type of underlying cause[229]. It is also considered that only a part of these delays could be reduced with the solutions proposed. Finally, the estimate is scaled up with traffic growth at horizon 2035.

The calculation and rationale for resilience are summarised in Table 9.

Underlying cause of delays	% of flights	Delay per flight (min)	Potential reduction of delays
Staffing	1%	14	85%
Disruptions	0.3%	33	25%
Events	0.2%	14	80%
Weather	1%	20	20%

Table 9. En-route ATFM delays and reduction potentials by underlying cause[230]

[229] Performance Review Report 2017, PRR2017, Performance Review Commission, Eurocontrol, May 2018

[230] For columns 1 to 3, data comes from PRB Annual Monitoring Report 2016 Volume 1: European Overview Version: 1.0 Date: 9 October 2017. (Available at: https://webgate.ec.europa.eu/eusinglesky/content/prb-annual-monitoring-report-2016-volume-1_en . For column 4, data is from SJU estimates).

The additional resilience is estimated to **reduce overall delay by 38 million minutes** in the period 2019 and 2035 (from which 3 million minutes are saved in 2035).

In total, the overall improvements in capacity would result in 476 million of delay minutes saved in the period 2019-2030 which results in approximately EUR 34 billion in benefits[231].

G.3.2 Environment

The impact on the environmental footprint of aviation is assessed through the increase of horizontal flight efficiency thanks to seamless ECAC FRA, optimised airspace reorganisation and SESAR solutions as well as benefits linked to 4D trajectory implementation.

- Based on the results from the simulations conducted by NM, it has been estimated that improvements will bring a reduction of 7 to 13 Nautical Miles per flight in 2035 and between 4 and 10 Nautical Miles in 2030. Considering a linear increase in the reduction of Nautical Miles between 2018/2030 and 2030/2035 additionally to the fact that 1 Nautical Mile correspond to 11 kg of fuel burned[232], the total amount of fuel saved for all forecasted traffic has been determined. Between 2019 and 2035, savings in fuel consumption reduction are between EUR 2.6 and 5.8 billion.
- The operational efficiency linked to the implementation of 4D trajectory would bring benefits in term of fuel efficiency of EUR 22 million (considering 0.02% fuel efficiency according to the Master Plan) between 2025 and 2029 extrapolating from previous PCP estimates.

Considering the projected traffic forecast up to 2035, and linear increase in the reduction of NM saved, the total benefits is estimated between 30 and 60 millions of tons of C02 corresponding EUR 3-6 billion over the 2019-2035 time period.

G.3.3 Cost efficiency

The cost efficiency benefits have been addressed through the improvement of ANS productivity[233]. The estimation is based on the increase of the average sector load from current levels (62%) up to 70% by 2030 and 90% by 2035 in a limited number of ACCs. This is brought by the increase of capacity (with the introduction of productivity tools and airspace re-organisation) combined with the increased flexibility of the overall system (with flow centric operations and capacity-on-demand service). The estimated benefits are between EUR 5.1 and 6.6 billion.

[231] Considering the average price of a minute of delay of EUR 70 Standard Inputs for Eurocontrol Cost-Benefit Analyses, Edition 8, February 2018. (Available at: https://www.eurocontrol.int/documents/standard-inputs-eurocontrol-cost-benefit-analyses)
[232] Source: Standard Inputs for Eurocontrol Cost-Benefit Analyses – Edition 2015
[233] The calculation focuses on this metric and does not include other cost saving linked the rationalisation and optimising of CNS or structural changes in ANSP models.

It is also considered that the ANSP productivity linked to the implementation of 4D trajectory[234] would bring benefits in terms of ANSP cost efficiency of EUR 164 million between 2025 and 2029, based on estimates calculated for the PCP.

Total ANS productivity benefits considered for cost efficiency are estimated between EUR 5 and 7 billion from 2019 to 2035.

G.4 Investment needs

The investments needs for the following improvements are included:

- ECAC-wide Airspace redesign (EUR 0.5 billion);
- Next generation performance based air-ground communications environment [235] (EUR 3.9 billion);
- Roll-out of an operational harmonisation program across ACCs (EUR 0.3 billion);
- Investments required for the deployment of SESAR automation solutions up to the SESAR 2020 package (EUR 1.2-5.6 billion);
- Validation and controller training costs (EUR 0.1 billion);
- Transition of data service provision from ACCs to ATM data service providers (ADSP) (EUR 0.3 billion);
- Deployment costs of 4D services (EUR 0.5 billion);
- Initial implementation of flight centric operation (EUR 0.5 billion).

The investments are derived from estimates available through the European ATM Master Plan update campaign and complemented by SJU estimates.

Overall, total investments for all improvements described above are estimated between EUR 7 and 11 billion over the 2019-2035 period.

G.5 Net benefits

Investments and benefits have been determined on an annual basis between 2019 and 2035 both for the lower and upper range as it is presented in Figure 61 and Figure 62.

[234] 1.25% gain in ANSP productivity according to the Master Plan

[235] For the forecasted IFR fleet (including scheduled and regional airlines, military and business aviation).

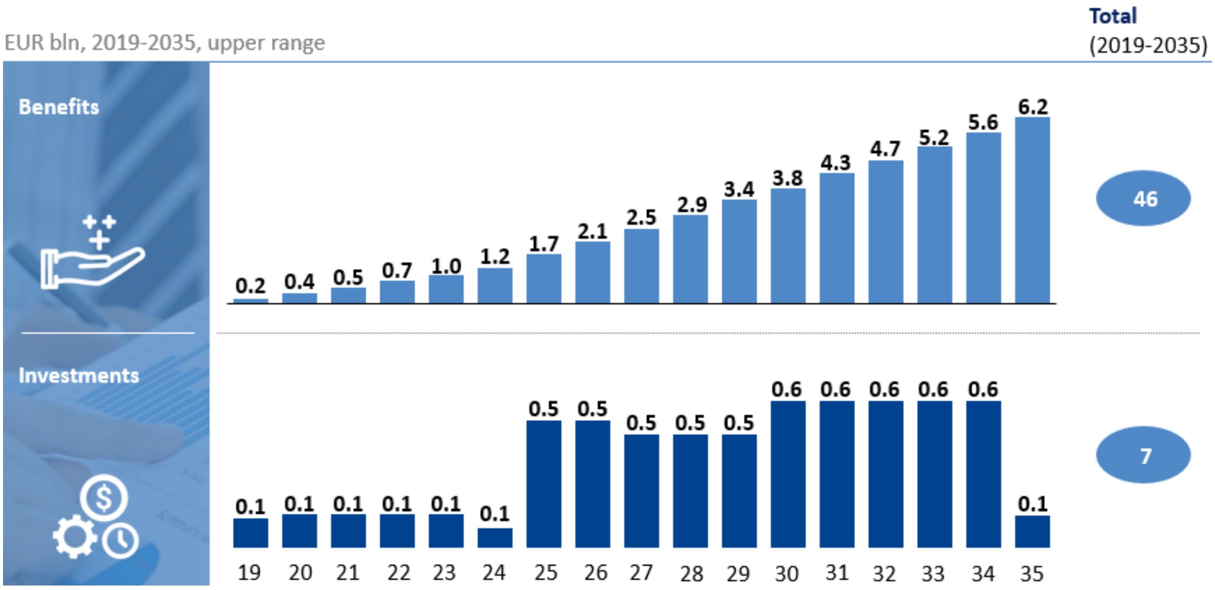

Figure 61. Annual ramp-up of benefits and investments between 2019 and 2035 for the upper range

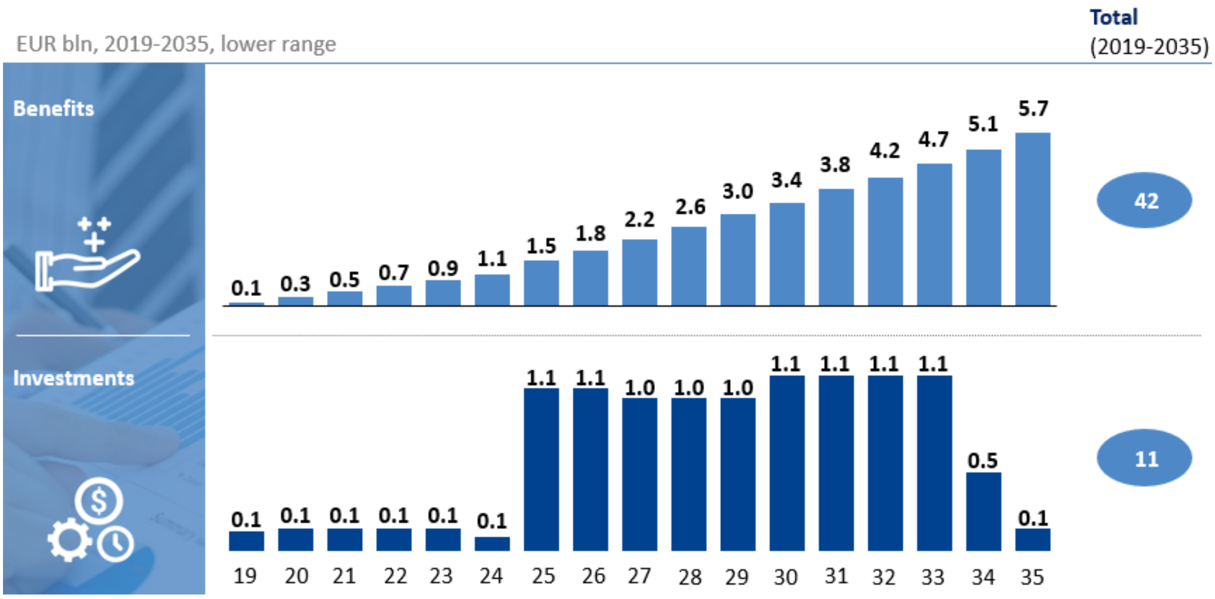

Figure 62. Annual ramp-up of benefits and investments between 2019 and 2035 for the lower range

The net benefits, including net present value (NPV), are summarised in Table 10.

	Upper range	Lower range
Net benefits	40	31
Net private value	17	13

Table 10. Summary of impact assessment analysis for the 2019-2035 period

G.6 Sensitivity analyses

Three sensitivity analysis were conducted to test the robustness of the CBA results under different assumptions. Results are summarised in Figure 63.

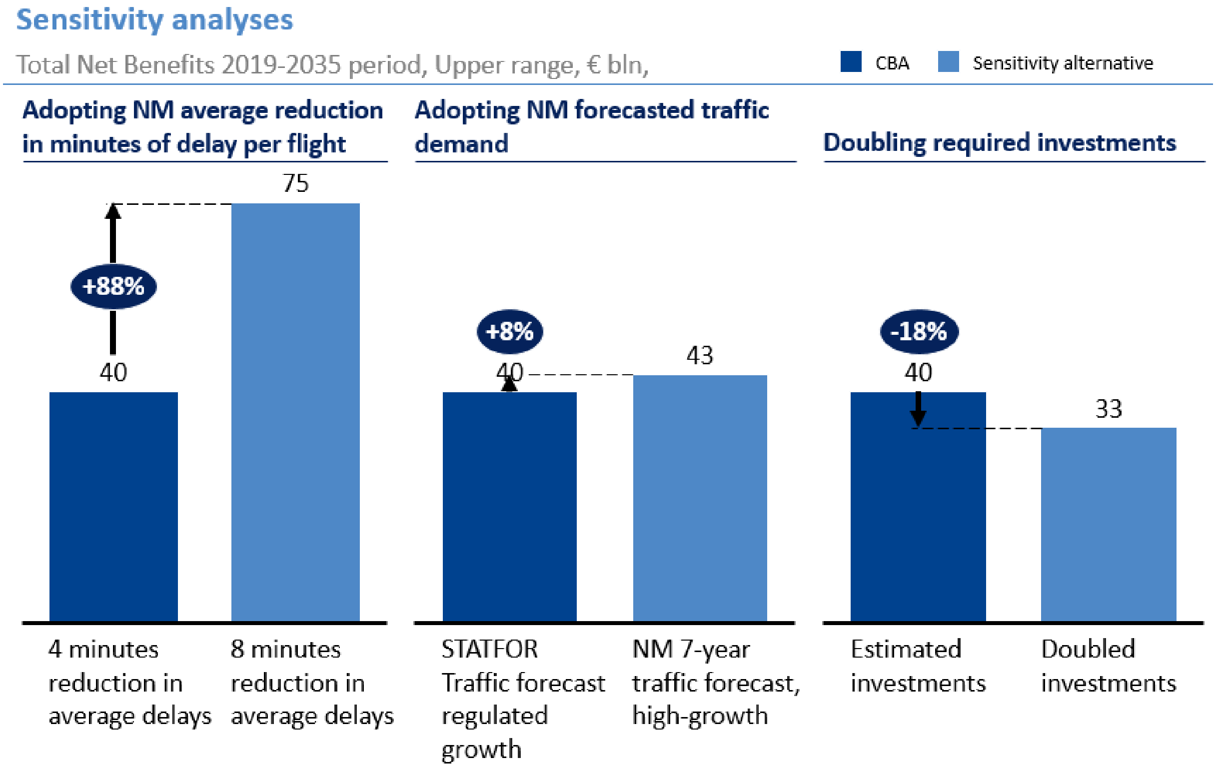

Figure 63. Sensitivity analysis for total net benefits (2019-2035)

These results show that even by changing the main hypothesis made (i.e., delay reduction, traffic forecast and needed investments), the net benefits would still remain largely positive and thus sustain the conclusion for the feasibility of full implementation of the transition strategy.

G.6.1 Sensitivity analysis on benefits related to delay reduction

The analysis performed for benefits takes a conservative approach based on the MP performance ambitions. The results from the simulations conducted by NM forecast more delay reduction. The objective is to use the results from the simulations to assess the gains in delay reduction and therefore the impact on the net benefits.

- Current assumptions for delay reduction: **4.0 min per flight** in 2035 based on MP and estimated gains from the resilience (see section G.3.1)

- New assumption for sensitivity analysis: delay reduction of **8.0 minutes per flight** in 2035[236]; which has been spread from 0 minutes in 2018 up to 8 minutes in 2035

This assumption would vastly increase the Net Benefits by **EUR 35 billion** over the 2019-2035 period, or **88%,** compared to the CBA analysis.

G.6.2 Sensitivity analysis related to assumptions on traffic forecast

For traffic forecast, a conservative approach aligned with the assumptions of the MP has been chosen. The objective of this sensitivity analysis is to assess the benefits if a higher traffic forecast had been applied.

- Current assumptions: STATFOR regulated growth scenario (same approach as in the MP) being one of the most conservative scenarios
- New assumptions for sensitivity analyses corresponds to a high growth scenario similar to the approach taken by NM for the simulations (see Annex D): NM Eurocontrol 7-year "between traffic growth forecast"[237] until 2024, then the annual growth between 2023 and 2024 (3.1%) applied yearly up to 2035.

ECAC		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	AAGR 2018-2024	RP2 2015-2019 AAGR	RP3 2020-2024 AAGR
IFR Flight Movements (Thousands)	H	.	.	.	.	11,089	11,494	12,036	12,425	12,836	13,255	13,669	**3.7%**	**3.3%**	**3.5%**
	B	9,770	9,923	10,197	10,604	10,957	11,245	11,524	11,738	11,969	12,176	12,405	**2.3%**	**2.9%**	**2.0%**
	L	.	.	.	.	10,826	10,995	11,058	11,095	11,176	11,226	11,300	**0.9%**	**2.4%**	**0.5%**
Annual Growth (compared to previous year unless otherwise mentioned)	H	.	.	.	.	4.6%	3.6%	4.7%	3.2%	3.3%	3.3%	3.1%	**3.7%**	**3.3%**	**3.5%**
	B	1.7%	1.6%	2.8%	4.0%	3.3%	2.6%	2.5%	1.9%	2.0%	1.7%	1.9%	**2.3%**	**2.9%**	**2.0%**
	L	.	.	.	.	2.1%	1.6%	0.6%	0.3%	0.7%	0.4%	0.7%	**0.9%**	**2.4%**	**0.5%**

Table 11. Traffic forecast assumptions for sensitivity analysis[238]

As such, increasing the number of flights but keeping the same value of benefits per flight would bring an increase in total benefits and therefore increasing the net benefits by EUR 3 billion or 8%.

G.6.3 Sensitivity analysis related to investments

The objective of this sensitivity analyses is to assess the impact if the total estimated investments covered by all improvement opportunities in the focuses areas are doubled.

236 The AS-IS simulation shows a delay of 8.5 minutes per flight in 2035. Considering an achievable delay of 0.5 minute per flight with the target AAS, a potential reduction of 8 minutes has been applied.
237 Line B of the table corresponds to the average between high and low forecast
238 Eurocontrol Seven-Year Forecast February 2018 (Available at: https://www.eurocontrol.int/publications/eurocontrol-seven-year-forecast-february-2018)

- Current assessment of costs: EUR 7 – 11
- New assumption for sensitivity analysis: EUR 14 – 22 billion

Considering the benefits would be the same (EUR 42-47 billion), if investments costs are doubled, the nets benefits would be **EUR 20 – 33 billion** between 2019 and 2035 (compared to EUR 31-40 billion).

As such, doubling investments would lead to a reduction of 18% of the net benefits between 2019 and 2035 (when comparing the upper range).

G.7 Limits of the analysis performed

It is recognised that a high-level impact assessment is just the first step and that further work will be required in the future.

The impact assessment has the following limits on scope and depth:

- The study has considered a long time horizon and therefore operational and technical concepts are at different levels of maturity. The simulations and impact assessment are therefore based on high-level assumptions that must be tested as concepts mature.
- The high-level impact assessment does not provide a view of the social and safety implications as well as State-specific impacts such as the impact on the military.
- The fast time simulations integrating advanced SESAR solutions are based on validation targets and expert judgement of workload improvements that have not yet been subject to validation through real time simulations. Similarly, the impact assessment is a high-level assessment based on the available data and high-level assumptions consistent with the European ATM Master Plan.

G.8 Conclusion

The key simulation result from the Network Manager is that current arrangements for capacity enhancement would lead to severe network congestions and average delay of up to 8.5 minutes per flight in 2035. Implementing the proposed target architecture (including the airspace optimisation and operational harmonisation) would bring delays back in line with the SES target (0.5 minutes average en-route delay per flight). The main benefit is therefore avoiding the high cost of delay; a conservative estimate of this benefit is EUR 34 billion. There are additional benefits realised through increased ANS productivity of EUR 5-7 billion and a significant decrease in the environment footprint of aviation (monetised at EUR 3 to 6 Bn).

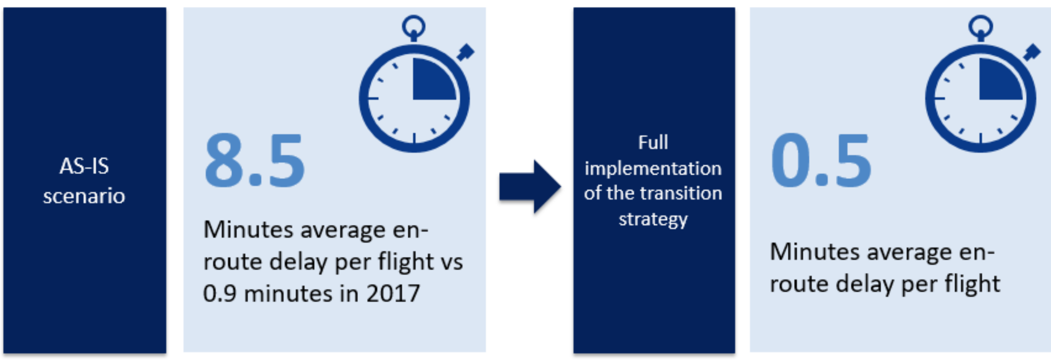

Figure 64. Key delay statistics from simulations conducted by the Network Manager

The overall results of the economic analysis indicate a considerable potential to realise a **net benefit of EUR 31-40 billion** (or EUR 13-17 billion in NPV) over the 2019-2035 period. A **sensitivity analysis** was conducted to test the robustness of the economic analysis under different assumptions (addressing main areas of uncertainty linked to simulation results, traffic forecasts and investment estimations). Details on the sensitivity analysis are available in Annex H.

The impact assessment results **are sufficient to demonstrate that investing in a solution to the anticipated capacity issues is essential for the future of European aviation**.

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