Proposal for the future architecture of the European airspace

Workshop pre-read material

Status: Final
Classification: Public

Abstract
To support workshop discussions with stakeholders, this document is intended to provide a snapshot of the work to date, focussing on the proposed target architecture, transition strategy and emerging recommendations. The content of this document should not be considered final.
1 Analysis re-confirms that if we do not manage to make some clear changes the delay situation will continue to deteriorate to an unprecedented level

Current traffic forecasts are predicting a return to a sustained period of growth. As illustrated in Figure 1, STATFOR’s (Eurocontrol’s Statistic and Forecast Service) latest long-term traffic growth scenario 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 per cent. At the same time 2018 shows a rapid deterioration in delays during the summer season linked to this growth in traffic. These developments create a major challenge for the ATM (Air Traffic Management) industry, which will have to adapt to them and handle them safely, efficiently and at an economically acceptable cost.

Figure 1. Traffic growth forecast from Challenges of Growth Annex 1, and 2018 delays compared to 2017

Figure 2 illustrates the results of a simulation performed by the Network Manager1 (NM) at the 2035 horizon:

Figure 2. Key simulation results reflecting a “do nothing” scenario at 2035 horizon

The predicted levels of delays are unprecedented and significantly higher than the highest annual delay ever recorded in the network (4.5 minutes in 1999 during the Kosovo crisis).

1 Further details on the simulations are presented in a separate Annex.
2 This is not a new problem and in the long run it cannot be solved with the same approach as in the past

As part of the study the current en-route architecture has been analysed. Table 1 summarises the operational issues 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. The need to address these issues formed the basis upon which the proposed target architecture has been designed.

<table>
<thead>
<tr>
<th>Factors limiting overall capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-optimal organisation of airspace</td>
</tr>
<tr>
<td>• The current airspace organisation is not yet fully optimised to network flows and makes limited use of cross-FIR cooperation.</td>
</tr>
<tr>
<td>Limited use of data communications</td>
</tr>
<tr>
<td>• The current voice intensive process leads to high saturation of radio frequencies and can lead to voice communications being a constraining factor in determining sector capacity.</td>
</tr>
<tr>
<td>Limited availability of VHF frequencies</td>
</tr>
<tr>
<td>• Limited availability of new frequencies potentially prohibits sector creation.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Factors limiting capacity scalability and resilience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited information sharing and interoperability</td>
</tr>
<tr>
<td>• Current limits on interoperability and data sharing lead to sub-optimisation.</td>
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<tr>
<td>• Suboptimal view and usage of effective available airspace at network level.</td>
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<tr>
<td>Limited flexibility in the use of ATCO resources across ACCs</td>
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<tr>
<td>• ATCO qualifications are in most centres optimised for a limited number of airspace configurations.</td>
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<tr>
<td>Limited predictability</td>
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<tr>
<td>• High buffers across the planning and execution phases due to limited predictability reduce the actual usage of existing capacity.</td>
</tr>
<tr>
<td>• Lack of end-to-end 4D trajectory optimisation during both planning and execution phases mean that the capacity potential cannot be achieved at network level.</td>
</tr>
<tr>
<td>Limited automation support for ATCOs</td>
</tr>
<tr>
<td>• Limited automation support means significant human effort is still required to manage traffic. The system as a result lacks scalability to meet growing demand.</td>
</tr>
</tbody>
</table>

Table 1. Current operational issues

Further splitting of existing sectors is becoming operationally impractical and is likely to be both ineffective and highly costly in the long term.
3 The proposed problem solving approach addresses two sides of the same capacity challenge

The objective of this study is to propose a future airspace architecture, and an associated transition strategy, that 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 Single European Sky.

The scope of the study is defined according to the five analytical layers as illustrated in Figure 3.

The focus of the study is the link between the technical layers with the intent to propose a new airspace architecture that ensures airspace is optimised according to operational needs and without undue regard for FIRs or national boundaries. It is the first time that such a close coupling between different layers has been undertaken in the context of SESAR.

In line with the European ATM Master Plan and the wider EU digitalisation agenda the deployment of SESAR Solutions in the technical layers enables more flexibility and robustness in the airspace layer 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 as illustrated below.
The framework layers — service and regulatory — enable the achievement of the proposed architecture. Evolutions of these layers is strongly coupled to the proposed architecture and the associated potential performance. The study identifies potential issues and implications for these layers.

To ensure a clear traceability between the problems and solutions, proposed changes related to the technical layers are grouped into two focus areas addressing respectively two core challenges — Capacity and Airspace, and Scalability and Resilience - as presented in Figure 5 below and further developed in the next section.
4 The proposed future airspace architecture relies on optimised airspace organisation, supported by progressively higher levels of automation and common ATM data 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: *a seamless European en-route airspace, 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 new architecture should:

- Support development of ATM capacity and scalability 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.
- Continue to facilitate the civil and military access to European airspace.

The solutions are grouped into focus areas:

**Focus area 1: Airspace and Capacity**

- **Optimised airspace organisation** – Solutions that support improved design and use of airspace.
- **Operational harmonisation** - Aligning centre’s capacity and ways of working to best practices through systematic operational improvement.
- **Automation and productivity tools** – Increased automation as a progressive enabler of Trajectory Based Operations with short, medium and long term enhancements to provide increased capacity and predictability.

**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.
- **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).
- **Sector-independent Air Traffic Service operations** - Automation support for controllers to enable provision of ATC without the need for sector specific training and rating. Training and certification to be based on traffic complexity, instead of sector specificities.
- **Trajectory based operations and increased sharing of information to address predictability** - Deployment of SWIM, 4D trajectory exchange.
- **If proven feasible, the implementation of 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.

Table 2. Solutions for delivering the Target Architecture per focus area
There are dependencies between most solutions: both advanced airspace concepts and service orientation have a strong link to automation, which in turn requires improved air-ground communications. A more scalable ATM is the result of combining airspace enablers, automation and service orientation.

4.1 Focus area 1: Airspace and capacity

4.1.1 Optimised airspace organisation

4.1.1.1 ECAC-wide Free Route Airspace and Flexible Use of Airspace

The objective of Free Route Airspace (FRA) is to increase flight efficiency. In itself, it does not contribute to an increase of capacity or resilience of the ATM system. However, as it is transforming the operational environment in which flights are being planned and executed we felt that it is important to reflect this transformation as a starting point for this study.

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. 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).

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 Free Route Airspace, will rely on 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.

It is also worth noting that 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), 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.

4.1.1.2 Optimised cross-FIR sectorisation

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.

Figure 6 illustrates a potential ECAC-wide airspace design that has been developed as part of this study by the Network Manager using the aforementioned principles, 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.
Further information on the methodology applied by the Network Manager to identify airspace design improvements can be found in the supporting annex for the workshop pre-read material.

4.1.2 Operational harmonisation

In support of the optimised airspace organisation, a process of operational harmonisation is required. 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% of ACCs. It should also lead to a more harmonised operational concept and increased levels of inter-ACC interoperability.

The nature of the actions depend on the local specificities of each ANSP, and may include recruiting additional controllers, improving rostering and other operational issues. Operational harmonisation includes as well completion of PCP deployment.

4.1.3 Automation and productivity tools

Automation support for controllers is the basis for the implementation of Trajectory Based Operations (TBO) and is therefore a key element of the future architecture. The scope of the selected solutions is based on achievement of Phase C of SESAR rollout as defined in the European ATM Master Plan. Solutions in Phase D are not in the scope of this study and will need further research.

Indeed, automation is central in the SESAR programme and is a key priority of the European ATM Master Plan. SESAR 1 and SESAR 2020 deliver concrete automation solutions, primarily in the form of support to decision making, that help improve the overall performance of the ATM system and serve the goals of the airspace architecture study. The figure below depicts the SESAR automation solutions proposed to be referenced in the study.
### Delivered in SESAR 1

- 4D Trajectory Exchange *(Solution #115)*
- Extended Arrival Management horizon *(Solution #5)*
- Advanced short ATFCM measures, STAM *(Solution #17)*
- CTOT and TTA *(Solution #18)*
- Automated support for traffic complexity detection and resolution *(Solution #19)*
- MTCD and conformance monitoring tools *(Solution #27)*
- Extended flight plan *(Solution #37)*

### In the pipeline with SESAR 2020

- Extended arrival management across overlapping AMAN operations *(Solution #01-01)*
- Mission trajectory driven processes *(Solution #07-03)*
- Management of dynamic airspace configuration *(Solution #08-01)*
- Collaborative network management *(Solution #09-03)*
- Advanced separation management *(Solution #10-02b)*
- ATC planned trajectory performance improvement *(Solution #18-06a)*
- Improved performance in the provision of separation *(Solution #10-02a)*
- High productivity controller team organisation *(Solution #10-01a)*
- Trajectory based operations *(Solution #18-02a)*
- Network Prediction and Performance *(Solution #09-01)*
- Trajectory based planning system *(Candidate Solution #88)*
- RBT revision uplink supported by datalink increased automation *(Candidate Solution #57)*
- Automation supporting flight-centric ATC and improve distribution of separation responsibility in ATC *(Candidate Solution #73)*
- SWIM TI Purple profile for Air/Ground Safety-Critical Information Sharing *(Candidate Solution #100)*

Although not considered in the scope of this study, it is important to note that higher levels of automation will be needed in order to allow the necessary gains in capacity and resilience coping with the expected future growth and complexity in traffic. Figure 7 illustrates an automation model being developed in the frame of the Master Plan update campaign that mirrors the SAE (Society of Automotive Engineers) 5 levels model (from level 0 “no automation” to level 5 “full automation”) widely adopted by the automotive industry.
Furthermore, from one level of automation to the next one, the role and responsibilities of the controller will progressively change. As depicted in Figure 7, there will be an evolution towards a partnership between human and machine, where each has their roles and trusts the other to perform their roles (with appropriate safety assurance means 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. It is important to note that the airspace study does not consider a dramatic change of the current human responsibilities.

4.2 Focus area 2: Scalability and Resilience

4.2.1 A progressive introduction of a new service oriented architecture

Solutions presented in this section respond to a need for a more dynamic management of capacity that takes advantage of digital technologies, so that the ATM system is more flexible, scalable and resilient.

Figure 8 illustrates the proposed high-level logical architecture designed to enable vertical decoupling of services. The idea here is not to prescribe specific implementation choices, but merely to provide a flexible architecture that allows stakeholders to choose 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-bundling of services into horizontal consolidation, increasing flexibility, scalability and resilience.
When aiming to de-couple 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 CNS systems that send and/or receive radio signals, as well as meteorological sensors. The aircraft operated by the airspace users have also 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.

4.2.1.1 Virtualisation and ATM data as services

A virtual centre is one or more Air Traffic Service Units (ATSU) 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.

A Virtual Centre is composed of the following services, which could be provided independently from another. The geographically fixed services include the provision of “CNS infrastructure and services” for which, even though geographically fixed, the provider could be decoupled from the ANSP, similar to weather services.

Figure 8. Proposed Service Oriented Architecture depicting service (not information exchange) flows
Air Traffic Services

ATS is the 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.

ATM data services

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.

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 standardises interfaces, they can be built up from different underlying 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 sensors and surveillance sensors and the provision of air-ground antenna.

Table 3. Example of services that can be provided independently

In addition, the architecture also requires

- Network Management functions, including Air Traffic Flow and Capacity Management (ATFCM), existing Network Functions and Network Crisis Management.
- Transversal services: SWIM, communications and security services – including CNS enhancements (see below).

4.2.1.2 CNS enhancements

CNS enhancements include both rationalisation of the existing infrastructure and new technology. New technology will be required, including further enhancement to the Global Navigation Satellite Service to incorporate the Galileo system.

The key development however will be the transition to a new air-ground communications environment that supports voice over IP (VOIP) and accommodates a range of datalinks using the multilink concept and delivered through clearly identified services mandated at performance level.

How CNS technology is deployed and managed will also be improved through the “CNS Infrastructure and Services” concept moving to a performance-based provision of CNS by defining contractual relationships between customer/provider with clearly defined and European-wide harmonised services and quality.

4.2.2 Enabling higher capabilities and performance

The proposed architecture has the potential to enable new types of services that are more scalable to demand. The key to success is to allow existing or new service providers and new entrants to operate such services.
By enabling this type of new service, the new architecture is expected to lead to an increase in reliability in the en-route environment. 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.

4.2.2.1 Sector-independent Air Traffic Service

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.

It results in automation support on sector-specific aspects in support of controllers to provide ATC without the need for sector-specific training and rating. Training and certification can then be based on system functionalities and traffic complexity, instead of airspace/sector specificities.

4.2.2.2 Trajectory based operations and increased sharing of information to address predictability

Trajectory-based operations (TBO) takes a holistic look at the trajectory from start to finish. With it, airports, airspace users, ANSPs and the Network Manager have access to up-to-date flight, meteorological, airspace and aerodrome information, and a coordinated and synchronised view of the trajectory throughout the operations, from the planning through to the flight operations phase. In very many ways, TBO acts as a glue that binds together the many inter-dependent factors that affect the trajectory. In the proposed new architecture, air-ground 4D trajectory exchange supports completion of the TBO concept by enabling all users of flight data to have a common view of the evolving traffic situation for all phases of flight.

4.2.2.3 If proven feasible and where applicable, the implementation of flight/flow 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.

Together with virtualisation, the flight-centric concept would allow for flight-centric distributed teams, where ANSPs can pool resources by delegating services rather than airspace.

5 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. This section explores the introduction of a capacity on demand service and the creation of dedicated ATM Data Service Providers (ADSPs) in order to identify targeted support to early movers in implementing high-impact operational improvements or the shift to new delivery models.

5.1 Capacity on demand
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. The current system, relying on provision of local ATM services on a defined territory, demonstrates limited resilience to such disturbances.

Enabled by the proposed architecture, the goal of the “capacity of demand” service is to ensure the continuity of air traffic services by temporarily decoupling the controller working position (CWP) from the airspace served.

Rather than mandating shared management of the airspace 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 9) while maintaining a network-centric approach.

The goal is to enable horizontal one-on-one collaboration for ANSPs to let them develop their own model for resilient Air Traffic Service

![Diagram showing the goal of enabling horizontal one-on-one collaboration for ANSPs to develop their own model for resilient Air Traffic Service.](image)

Figure 9. Example of capacity on demand service delivery model

### 5.2 ATM data service provision

Currently, air traffic services are almost-fully provided by vertically integrated national ATS providers who are jointly responsible for (i) producing the data required for ATS, (ii) processing and combining this data to make it available to Air Traffic Controllers and (iii) using that data to provide ATS for airspace users. This implies that data is currently not fully shared between ATS providers.

Creating a resilient ATM system will require a partial evolution of this model: shared management of the airspace, through remote provision of ATM services, will only be possible if all needed ATM data is available to remote ACCs. As illustrated in Figure 10 below, this could be achieved by supporting the progressive shift to a new service delivery model for ATM Data (comprising CNS, MET, AIS and Flight),
through the establishment of dedicated “Air Traffic Management Data Service Providers” (ADSPs). In this model:

- ANSPs that wish to remain in the current vertically integrated model could continue to do so;
- However, ANSPs would be incentivised to shift to a new model in which they would acquire their ATM data services from a provider on a voluntary basis;
- In addition, all ADSPs should be required to be interoperable to exchange information based on European or ICAO standards.

This new model would create the opportunity to:

- Support the creation of alliances among industry players and/or create specialised ADSP focusing only on a certain part of the “data service” value chain;
- Let each ANSP decide on the delivery model best suited to their specificities.

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

5.3 Targeted incentives for early movers

In addition to the current regulatory landscape, specific incentives could be put in place for those actors that are the first to implement recommended operational improvements or that shift towards innovative delivery models. This section presents an illustrative list of such potential incentives examples (not exhaustive).

For airspace users
• Incentives could be provided for airspace users to invest in SESAR related technologies by lowering en-route charges for those having installed it (for example through modulation of charges) ensuring that they pay only for services uses;
• Additionally, or alternatively, preferential ATM 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 and service delivery during performance scheme implementation to support the transition;
• Allow a profit margin to be made for 1-on-1 agreement of provision of remote ATS capacity (resilient services);
• Reward the achievement of specific 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 actors installing new systems and services.
• European guarantees (equity or debt) could be provided for the first actors to enter the market or shift to a new delivery model (e.g., first ANSPs creating a joint ADSP);
• Direct financial support mechanism (e.g., conditioned grants, faster depreciation of legacy assets) could be introduced to stimulate the launch of ADSPs meeting certain desired conditions (e.g., transfer of CNS infrastructure to a new ADSP entity, ADSP covering more than one State).

6 A possible way forward by bringing progressive transition every 5 years

A successful transition will only be possible through collaboration and commitment effort from all ATM stakeholders (not only ANSPs) to be successful. 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.
6.1.1 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.

<table>
<thead>
<tr>
<th>Milestone</th>
<th>High-level description</th>
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<tbody>
<tr>
<td>1. ECAC-wide implementation of cross-border Free Route, IOP and datalink</td>
<td>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 layer of ATM operations. 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.</td>
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<tr>
<td>2. Complete airspace re-configuration supported by an operational excellence programme to capture quick wins</td>
<td>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. This new initiative would be supported by an operational excellence programme which would aim at identifying best practices and capture quick wins (through changes in operational procedures, rostering, smaller adaptation of systems etc.) among all stakeholders and effectively support their implementation to reduce delays.</td>
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</table>
3. **Set up an enabling framework** for ATM Data Service Providers, capacity on demand service and rewards for early movers, first ADSP is certified

It aims at providing guidelines and an appropriate legal framework enabling the set-up of ADSP and the “capacity on demand” service. The aim would be to encourage willing to implement the new concepts as soon as they are made available.

### 6.1.2 By 2030

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<th>High-level description</th>
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<tr>
<td>4. Implement Virtual Centre and dynamic airspace configuration at large scale</td>
<td>The Virtual Centre is a key enabler for the resilience of the ATM system. Dynamic airspace configuration (DAC) 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 in 2020; their deployment by 2035 is to be secured.</td>
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<tr>
<td>5. Gradual move towards higher levels of automation supported by the implementation of SESAR Solutions</td>
<td>In the context of SESAR 2020, further SESAR automation solutions will gradually be made available before 2024. Deployment of these solutions should be incentivised for early movers as referred to in section 5 of this report.</td>
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<tr>
<td>6. Capacity on demand arrangements implemented across Europe</td>
<td>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 common data services layer.</td>
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<tr>
<td>7. New ATM data service provision model is implemented across Europe</td>
<td>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.</td>
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### 6.1.3 By 2035

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<tr>
<td>8. Transformation to flight/flow centric operations</td>
<td>The gradual implementation of the flight/flow centric concept is subject to the validation of the SESAR solution “Flight Centred ATC” supported by the relevant ATC tools and system adaptation.</td>
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<tr>
<td>9. Trajectory-based operations</td>
<td>TBO is the ICAO and SESAR 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.</td>
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<tr>
<td>10. Service-oriented air traffic management</td>
<td>It is inherent to the structural change of the EU ATM system to be more flexibility and provide resilience and scalability.</td>
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From the perspective of stakeholder groups, the main anticipated changes are:
From the perspective of professional staff, the main anticipated changes are:

<table>
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<th>Group</th>
<th>Main changes</th>
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<tr>
<td>ATCO</td>
<td>Greater operational harmonisation across ANSPs, including a transition to TBO will require significant changes to the 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. The most fundamental change would be where Flight Centric operations are adopted. Once the automation enablers to provide ATC sector independent are in place, ATCO qualifications will be optimised for a higher number of airspace configurations.</td>
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<tr>
<td>ATSEP</td>
<td>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 need to evolve to take on these new responsibilities.</td>
</tr>
<tr>
<td>AOC/Pilot</td>
<td>Support increased predictability by updating flight plans prior to flight and the agreed reference trajectory.</td>
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7 Preliminary impact assessment

This section presents a preliminary high-level estimation of the network performance impact of the targeted architecture and associated transition strategy for 3 of the SES KPAs: capacity, environment and cost efficiency that could be quantified.

The quantification was performed based on a top-down approach triangulating simulation results from the Network Manager (see further details in the Annex), SESAR Validation Targets as well as the overall SESAR performance ambition defined in the European ATM Master Plan (including investment needs) to ensure the highest level of consistency. Results, summarised in the table below, should be considered as rough orders of magnitude and will need further refinement and validation in the future as the deployment plans are defined.
## Impact (order of magnitude)

<table>
<thead>
<tr>
<th>KPA</th>
<th>Impact</th>
<th>Value € billion 2019-2035</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity</strong></td>
<td>The increase in capacity is linked to the introduction of SESAR technological solutions tackling en-route capacity combined with operational harmonisation and airspace reorganisation together with the already planned PCP implementation. All the above factors would bring around 438 million of delay minutes saved between 2019 and 2035 (from which 60 million minutes are saved in 2035). Increase in the resilience of the system would bring an additional delay reduction of approximately 3.5 million delay minutes in 2035. The additional impact on potential flight cancellation avoidance was not quantified due to lack of data.</td>
<td>34</td>
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<tr>
<td><strong>Environment</strong></td>
<td>The Network Manager simulation results indicate that in 2035, estimated improvement of flight efficiency between 7 and 13 Nautical Miles per flight can be achieved. This corresponds to a total reduction of approximately 100 to 200 million Nautical Miles flown in the network in 2035. Considering the projected traffic forecast to 2035, this result in between 77 and 143 kg of fuel saved per flight. This equates to total additional benefits between €3-6 billion over the 2019-2035 time period (considering only fuel costs and no other costs related to extra time for the crew, airframe, engines, etc.).</td>
<td>3-6</td>
</tr>
<tr>
<td><strong>Cost efficiency</strong></td>
<td>Collectively, total ANS productivity benefits are estimated to amount to €5-7 billion (or 57-73 € per flight in 2035) over the 2019-2035 period when compared to the cost related to further splitting of existing sectors to accommodate the growing traffic.</td>
<td>5-7</td>
</tr>
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</table>

Although the impact assessment is high level and based on at times very preliminary assumptions consistent with the wide range of maturity of the involved operational and technical enablers, a preliminary cost benefit analysis has also been conducted to estimate net benefits in terms of orders of magnitude.

Preliminary results of the CBA analysis indicate a considerable net benefits potential of €31-40 billion (or €13-17 billion in NPV) over the 2019-2035 period. Figures are presented in ranges due to high uncertainty levels (lower and upper range) and sensitivity analyses were 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 needs estimation).

Finally, key simulation results from the Network Manager reflecting a “do nothing” scenario at 2035 have been compared with the expected performance gains linked to a full implementation of the transition strategy proposed in the study. As it can be seen in Figure 12, the full implementation of the strategy would bring delays back in line with the SES target (0.5 minutes average en-route delay per flight).
Taken together, we assume that 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 Preliminary recommendations

Overall, we conclude that in addition to the planned rollout of the PCP in a timely manner, which includes key interoperability improvements for the ATM infrastructure, there is a pressing need to implement additional measures to contain the current capacity crisis.

Recommendation 1 – Launch airspace re-configuration supported by an Operational Excellence programme to achieve quick wins

- 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 and military should work together to achieve operational harmonisation aligning ACC capacity and ways of working to best practices through systematic operational excellence throughout the Network (also leading to geographically independent ATCO validations).

The Single European Sky (SES) initiative aims at improving the overall performance of ATM by moving a number of competences from an earlier intergovernmental practice to the framework of the European Union, as part of the Common Transport Policy. The current functional airspace block concept was created as a response to fragmentation in a radically different technology landscape (2009). Today, increased automation and virtualisation hold the greatest promise for effectively balancing supply (of air traffic control) and demand (flights) while 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) irrespectively of national borders of FABs. These forms of cooperation should be encouraged, as they are an effective vehicle to realise the vision of the SES.
Recommendation 2 – Realise virtual de-fragmentation of European skies

The Commission should:

- 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.
- Options could include the implementation of a certification and remuneration framework for ATM Data Services Providers (ADSPs) 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 target architecture.

The main policy instruments of the SES initiative, analysed in more detail by the European Court of Auditors\(^2\), form a coherent set which, in principle, would allow key problems identified to be tackled. They brought in a legal enforcement power coupled with financial and economic incentives, which should promote significant improvements. Based on the analysis conducted in this study, we concluded that certain adaptations 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 SES framework that rewards early movers

The Commission should review its incentivisation policy to reward actors who are the first to implement the high-level milestones identified in the proposed transition strategy.

9 Limits of the analysis performed during this study, and choices we had to make

It is recognised that a study of this nature is just the first step. Detailed work is now needed to build consensus on proposed architecture and how to achieve the transition. The study has the following limits on scope and depth:

- The scope of the study solely covers en-route airspace. Nevertheless connectivity between en-route and terminal airspace has been taken into account. The transition will need to take this fully into account. Other initiatives are required to increase gate to gate capacity including resolving issues with airport capacity.

\(^2\) European Court of Auditors Special Report 18: “Single European Sky: a changed culture but not a single sky”
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, 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 full implementation of the PCP and the operational harmonisation process. The simulations do not distinguish between the contribution from airspace re-configuration and operational harmonisation.

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.

The study is of a technical nature – it proposes a new architecture. It is recognised that successful implementation may require changes to the regulatory framework that will have to be further considered by the Commission and are not detailed in this study.

While recognising the importance of different types of airspace users, the study focussed on the flexibility required to support all airspace users and not the detailed technical issues for specific vehicles such as drones or general aviation (e.g. VFR traffic).

Benchmarking with other regions in the world was excluded from the report scope.

The proposed transition strategy is high-level, it does not describe a full roll-out plan including all steps recommended to be undertaken by stakeholders and associated governance.

In performing the study, a number of choices were made to steer the work:

- The target architecture is not an alternative to the European ATM Master Plan, rather it is a wider framework that will increase the benefits of SESAR deployment.
- The main performance focus was on capacity, scalability and resilience in order to ensure that the system can evolve to support the expected demand.
- The creation of a European Upper Information Region (EUIR) was not considered as central to the target architecture but rather as potential regulatory enabler.
- The architecture is scalable; the number of centres and operational units is not considered relevant within the study.