VIRTUALISATION IN ATM

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Virtualisation in ATM

Abstract

The Airspace Architecture Study (AAS) proposed a transition to a distributed architecture enabling significant performance increases in the European Air Traffic Management (ATM) system. Successful transition requires service providers to adopt new technologies, operational concepts, and business models.

The proposed architecture is based on three operational layers including the notion of a new form of service provider – the ATM Data Services Provider (ADSP) – which would enable certain services currently provided within an area control centre to be provided remotely.

Based on the findings of Project RoMiAD (Role of Markets in AAS Deployment) – a catalyst fund project of SESAR's Engage Knowledge Transfer Network – this whitepaper explores the definition of virtualisation and the role of markets in achieving a successful transition.

Engage

SESAR JOINT UNDERTAKING

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What is Virtualisation?

Let's start with some definitions

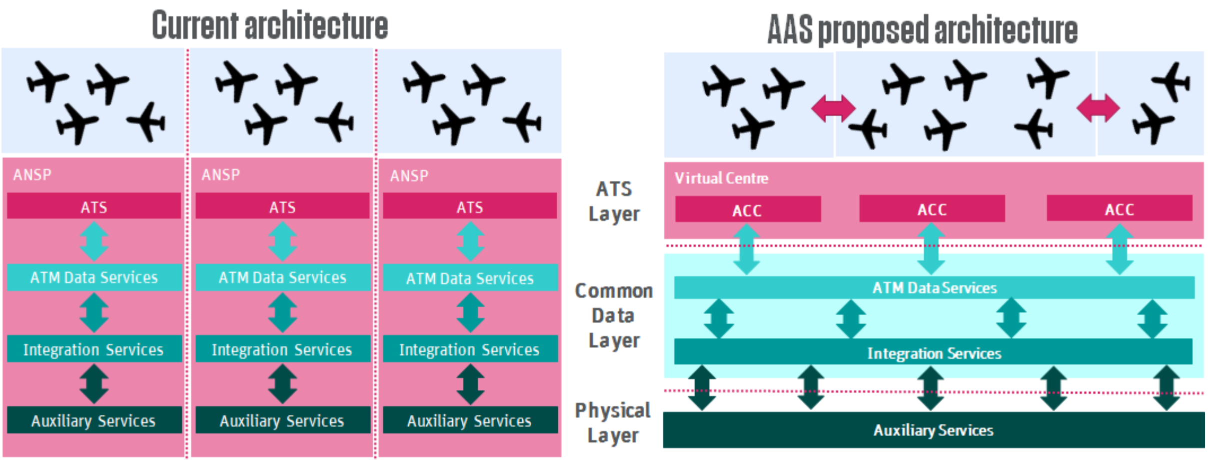
Before establishing how to incentivise virtualisation it is worth considering what is meant by digitisation, digitalisation and virtualisation.

Digitisation is the process of turning analogue signals in to digital signals. Digitisation in Air Traffic Management has been on-going for many decades – for example, the evolution of primary radar to secondary radar to Automatic Dependent Surveillance–Broadcast (ADS-B) – but is not yet complete. Many voice-only controller-pilot instructions still exist, and key agreements such as the letters of agreement between control centres are not digitised.

Digitalisation on the other hand is a transformative process of organisations taking advantage of digital technology including cloud based computing and high bandwidth communications. Digitalisation changes the way services are consumed from video rental to video on demand, from taxi cabs to Uber. New business models that use digital solutions to offer more flexible services. ATM is only scratching at the surface of digitalisation. There are two good reasons for this. Firstly, ATM is a safety critical service that relies on international interoperability. Whilst the current technology supports business critical applications such as banking, we are only just reaching maturity for safety critical applications and the specificity of Air Traffic Management.

The second reason is a lack of market forces. Most of the digitalisation successes were generated by new entrants disrupting existing markets. Blockbuster was replaced by Netflix. Taxicab drivers are supplanted by Uber drivers – often despite support from local majors for the status quo. Digitalisation is successful when consumer preferences for emerging business models drive reconfiguration within contestable markets. An interesting consideration for ATM modernisation is the extent that competitive markets for regulation are necessary to drive new business models.

Virtualisation is a specific form of digitalisation – a blue print if you will for the transformative process of digitalisation. Initially proposed by SESAR's Airspace Architecture Study the idea is simple: breakdown existing vertical (or National) silos to enable new forms of horizontal integration based on operational needs. The proposed solution enables flexible and scalable service provision enabling improvements in demand capacity planning and capacity deployment such that the ATM service is cost efficient and environmentally friendly.



The evolution was designed by considering the weaknesses in the current architecture. Today's ATM system is a patchwork of national air navigation service providers (ANSPs) operating vertically integrated systems. A single organisation therefore typically provides all the necessary services – from the auxiliary services (services with a geographical dependency such as Communications, Navigation, Surveillance (CNS), Aeronautical Information Services (AIS) and Meteorological Services (MET)) to Air Traffic Service (ATS). Airspace is mostly organised by national boundaries. Flight data is held locally in the ATM System (or Flight Data Processor (FDP)) – with limited sharing of data between neighbouring Area Control Centres (ACC) leading to restricted interoperability.

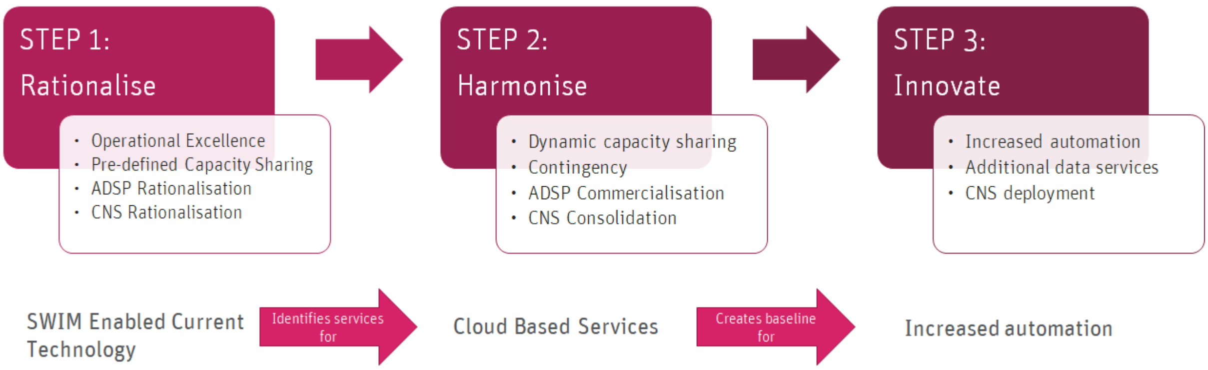
The technical limitations of the current architecture limit overall capacity, as well as flexible, scalable, resilient and coordinated deployment of new ATM functionalities.

The future system breaks down the current vertically integrated systems to enable a more efficient set of services to be integrated horizontally. The proposed architecture envisages three operational layers: ATS, common data and physical.

How can virtualisation be achieved?

Virtualisation of ATM is not simple and will not be achieved overnight. It is important therefore that a transition path exists with early benefits being realised whilst enabling the next steps and allowing different areas of Europe move at different paces.

Elaborating on the AAS transition plan, in the short term, **rationalisation** benefits are based largely on current technology, leading to additional benefits from greater **harmonisation** and eventually to **optimisation** including higher levels of automation. This section considers the potential benefits of each step in the three layers.



Step 1: Rationalise

The focus of first step is to use the principles of digitalisation to deliver benefits from the current generation of technology. This includes fully embracing System Wide Information Management (SWIM)[1] for all operation data exchanges and developing a robust infrastructure for ground-ground communications as envisaged by New Pan-European Network Service (NewPENS)[2] and the Single European Sky (SES) Digital Backbone. This supports benefits in the different layers:

- ATS Layer: Increasing Air Traffic Control Officer (ATCO) productivity through the Operational Excellence Plan (OEP) being developed by the Network Manager and initial steps towards capacity sharing between ACCs but only on predefined circumstances and usually within an ANSP or alliance.
- Common Data Layer: Potential rationalisation of ATM systems within the current paradigm.
- Physical Layer: Ability to rationalise CNS assets.

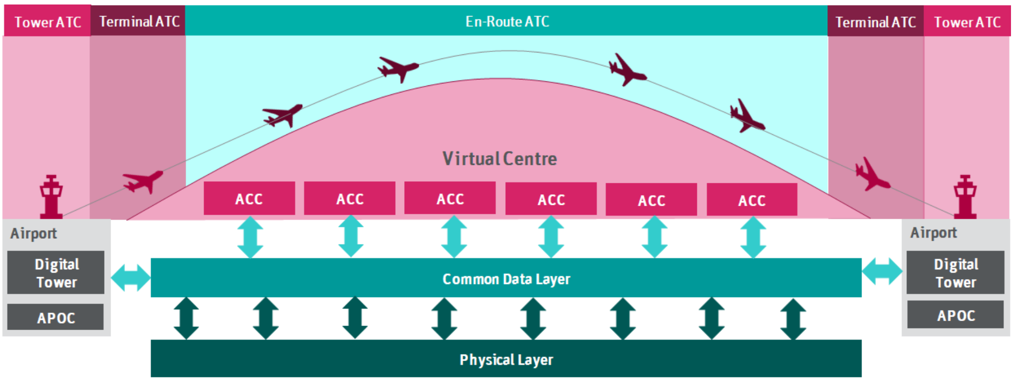
These benefits do not require virtualisation. However, the ANSP decision making process and subsequent organisational changes and motivation to achieve virtualisation provides an improved framework for general optimisation of ANS and accelerates non-virtualisation benefits.

Step 2: Harmonise

The focus of the second step is to harmonise operational concepts to allow dynamic sharing of capacity between ACCs. This is enabled by a shift from sector-based air traffic controller validation to validation of the system. In the Common Data Layer there is a transition to ATM Data Services as a set of harmonised cloud-based services – reducing cost of service provision and system upgrades. Finally, additional CNS assets are consolidated due to the ability to plan coverage at a wider geographic scope.

Step 3: Innovate

In this step, Trajectory Based Operations (TBO) is potentially ultimately realised and for any given gate to gate flight, all ACCs and Digital Towers are able to access the same flight data and propose resolutions to downstream conflicts early in the flight to avoid costly path stretching late in the flight.



This step uses the infrastructure established in step 2 to enable twofold benefits:

a) Increased productivity and efficiency due to new ATM functionalities; and
b) Reduced costs of deploying those new functionalities compared to the current architecture.

These benefits exist at all three layers (although the ATCO productivity benefit is only realised in the ATS Layer). Step 3 is the realisation of the Digital European Sky.

[1] SWIM enables service interfaces based on open standards.
[2] NewPENS is an evolution of the existing Pan-European Network Service (PENS) for ground-ground connectivity.

How big are the benefits?

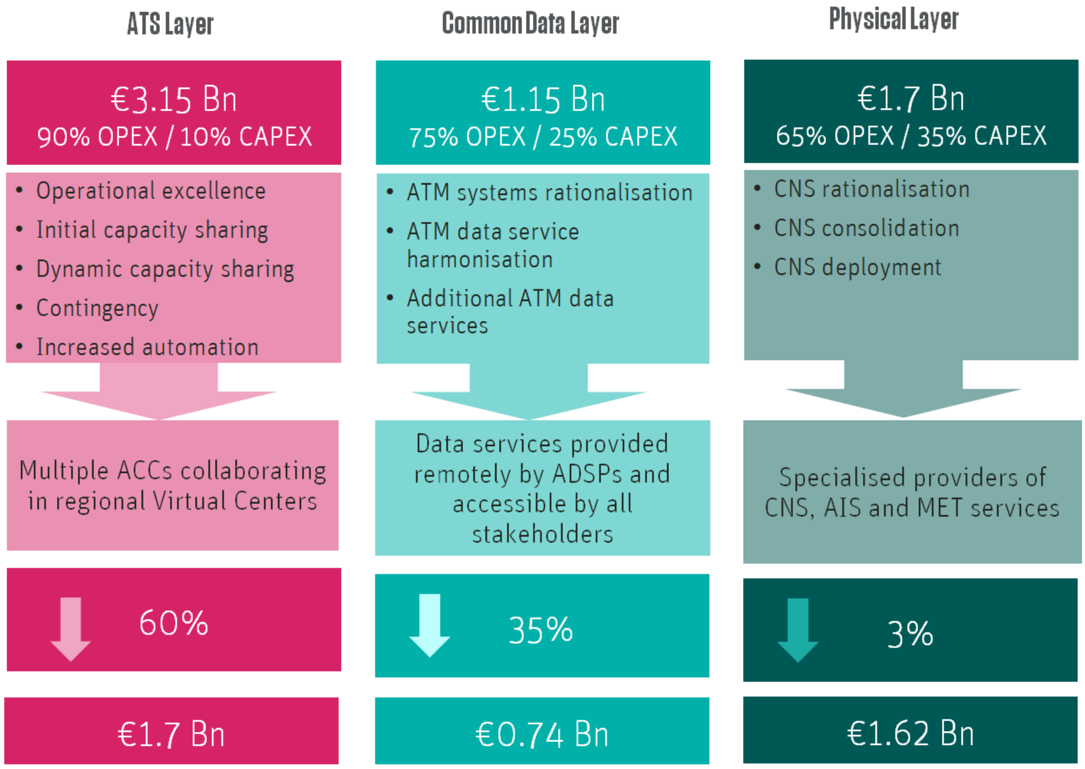
Reducing costs and delays

In 2018 the en-route ANS costs for the 30 States covered by the SES Performance Scheme in RP2 amounted to nearly €6 billion – excluding AIS, MET and exceptional costs. En-route Air Traffic Flow Management (ATFM) delay that year was 1.83 minutes per flight costing airlines an additional €1.35 billion in avoidable delay costs.

Our analysis shows that if virtualisation had been adopted before 2018 across Europe – ATM costs could have been 30% cheaper and en-route ATFM delay targets would have been met.

The total the upper bound of the potential benefit to Airspace Users (AUs) is in the order of €3.3 Bn per annum.

The impact per layer of virtualisation on the current cost bases is illustrated below.



Realising benefits in the ATS layer

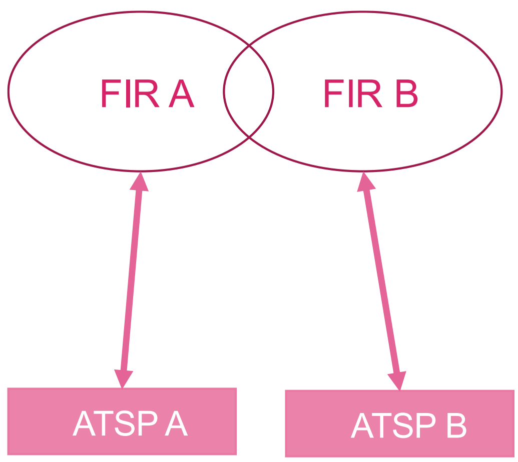
The ATS layer is the largest market with a size in 2018 of €3.15 billion out of the total €6 billion en-route ATM/CNS costs. The aim of modernisation in the ATS layer is to enable "inter-centre" collaborations leading to improved demand-capacity balancing and increased scalability, resilience and reduced environmental impact.

The ATS layer cost savings come from three main benefits: increasing ATCO productivity, capacity sharing and contingency.

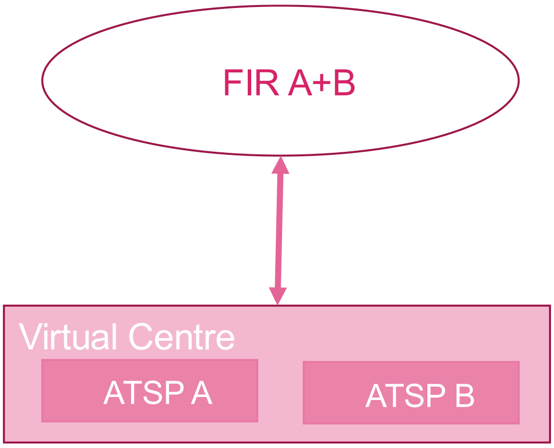
Step	Form of benefit	Description	Estimation method	Cost savings
Step 1	Operational Excellence	Increasing productivity to be best in class.	Reduced ATCO related costs as controller productivity increases to be best in class.	Up to € 980 m per annum
	Initial Capacity Sharing	Sharing capacity in limited pre-defined circumstances.	Ability to reduce delay within current sectorisation.	ATFM delay reduction
Step 2	Dynamic Capacity Sharing	Re-sectorisation along common design principles and harmonised operational concept supporting "any sector, anywhere".	Ability to handle the same amount of traffic with lower capacity "buffer".	Up to € 315 m per annum
	Contingency	Managing contingency at Virtual Centre level eases need for all Member States to have a national contingency arrangement.	Reduced cost of contingency arrangements.	Up to € 190 m per annum
Step 3	Increased automation	Adoption of a range of advanced SESAR Solutions.	TBD	TBD

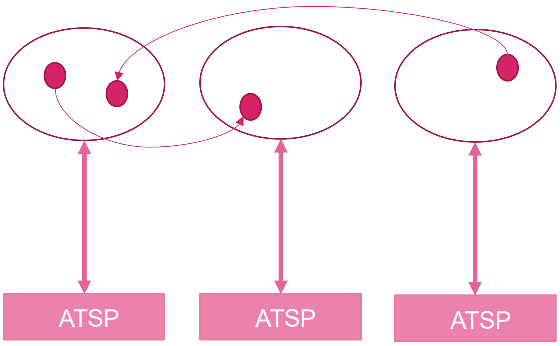
In the ATS layer, the benefits are achieved by Air Traffic Service Providers (ATSPs) collaborating to provide services whilst maintaining sovereignty. Collaboration encourages the behaviours to maximise the use of available capacity rather than organisational consolidation. Three forms of collaboration have emerged.

The first option is where ATS providers collaborate in terms of temporary ATS delegations to resolve operational issues. The idea is that ATS provider opens a sector on behalf of another that has insufficient resources to do so themselves. The point is the flexibility of the ATS provider to ask for help rather than create costly ATFM delay for the airlines. This type of solution already exists and new ways of delivering this type of benefit are being developed – for example the excellent FINEST project in Finland and Estonia which will see significant cross-border cooperation.



The second option really applies to an ANSP operating more than one ACC (but could also apply to neighbouring ATSPs operating as a joint venture). In this case several ATSUs are served by the same ADSP with the intent that they operate as if they were one centre. This is very much the skyguide's Virtual Centre concept. The benefits are derived from the additional flexibility to manage the combined airspace as a single Flight Information Region (FIR) and include ATCO rostering. There are no barriers to this option within an ANSP (and indeed the ANSP could decide to be their own ADSP). For multiple ANSPs there are wider considerations on joint certification and oversight of the Virtual Centre as well the probably more complex issue of sharing revenues.





The third option is when ATS delegation is enabled across multiple ANSPs in a region. The previous examples require controllers to be validated on a subset of sectors across the "virtual centre". In this option we really want controllers to be validated on the system rather than a sector so that they are able to "control any sector anywhere". This is ambitious, but potentially very beneficial. In Europe, each ANSPs has to build-in capacity buffers to deal with peak traffic, under this concept the buffer would only be needed at network level – this could actually reduce the cost of ATS by up to a third (or hopefully allow up to 3 times more traffic without significant ATFM delay).

A collaborative mechanism based on increasing levels of harmonisation (and then automation) is most likely to drive benefits in the ATS layer. The key issue is to understand how dynamic delegation of ATS can remove bottlenecks and delay from the network. For example, is it possible to:

- Create cross-border Virtual Centres based on key flows and choke points; and
- Inter Virtual Centre collaboration to support contingency and crisis management.

As an advanced concept "Capacity on Demand" offers two intriguing possibilities:

- Using ATS delegation as a means of "sharing" traffic between ATSPs in order to reduce traffic risk;
- Introducing a level of competition for the provision of additional capacity.

Both concepts offer potential to further reduce service provision costs by enabling better capacity planning and worthy of further consideration.

Realising benefits in the Common Data layer

To maximise the benefits available in the ATS layer, the common data layer needs to ensure that ATSPs (and other stakeholders) are able to subscribe to data for all concerned airspace. This requires integration of all necessary data using an accessible and secure IT infrastructure so that any ANSP, airline or airport can access the data and collaboratively make the best decisions for individual flights and the network.

The benefits of the common data layer are twofold. Firstly, as an enabler of the benefits in the ATS layer and to some extent the Physical Layer and secondly as a way of lowering the costs of providing ATM data services.

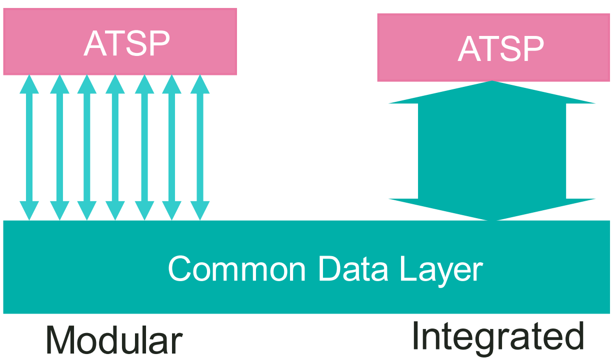
Step	Form of benefit	Description	Estimation method	Cost savings
Step 1	Data System Rationalisation	Consolidation of current ATM data systems and infrastructure (short term).	Reduction of FDPs (assumes infrastructure can be scaled up to regional requirements).	Up to € 80 m per annum
Step 2	ATM Data Service Harmonisation	Deployment of "cloud based" services (medium term).	Cost of "commercial" cloud services.	Up to € 340 m per annum
Step 3	Additional ATM data services	Synchronised deployment of new data services and enhanced innovation.	TBD	TBD

The services of the Common Data Layer are provided by ATM Data Service Providers (ADSPs). ADSPs will operate systems to provide these services remotely from ATSPs (although an ADSP could be collocated with an ATSP).

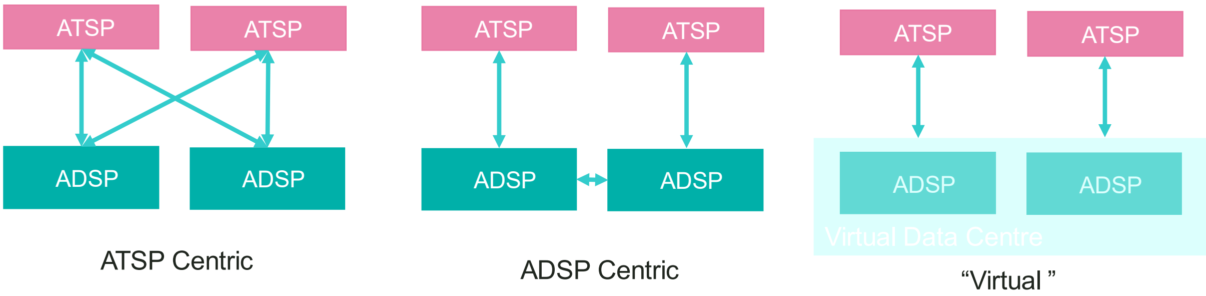
A design proposal or agreed architecture for the common data layer does not yet exist, nor the description of means of provision of ATM data services to the ATSPs. The key considerations are how ATM data services are bundled, and how the changes in ATS delegation are handled.

The approach to service bundling is dependent on where the integration of ATM data services is performed. The two basic approaches could be considered as "modular" and "integrated". In the modular case, the ATSP subscribes to a set of individual ATM data services and performs the integration for presentation to the controller. This option supports innovation by the ATSP and allows for specialist ADSP.

Alternative is that the ADSP performs the integration and presents data directly to the controller. This option allows the ADSP to innovate and potentially reduces ATSP costs as it leads to greater rationalisation.



When there is a change in the ATS delegation, the geographical scope of the ATM data services changes. Different models can support these scope changes.



In the **ATSP Centric** model each ADSP has a defined geographic scope, and the ATSP is responsible for subscribing to the group of ADSPs for all their airspace for which they have been delegated to provide ATS.

In the **ADSP Centric** model the ADSPs collaborate to provide full geographic scope of the ATM data services. The ATSPs subscribe to a selected ADSP, and does not need to re-subscribe when their "Area of Responsibility" changes.

In the longer term, the ADSP centric could be extended such that the common data layer appears to the ATSUs and other operational units such as Airport and Airline Operational Centres as a virtual data centre providing seamless access to all ATM data services for the pan-European network.

These two dimensions could actually apply to all ATM Data Services to individual business services such that ADSPs specialise in a specific services such as Datalink, Voice Communications or Flight Data.

Hence there is a bewildering array of options, some of which will be discarded as the technical solutions mature, but to some extend ATSPs and their suppliers need to decide how to provide the services – which is to some extent dependent on the form of collaboration being developed in the ATS layer.

In terms of ADSPs there are many options including:

- Groups of ANSPs could purchase a system and operate as an ADSP for their entire area of responsibility in which case the ATSP maintains the system development risk;
- ANSPs subscribe to a system owned and operated by the system manufacturer who acts as the ADSP and takes on the system development risk;
- A hybrid solution where ATSP and system suppliers collaborate (similar to the COOPANS) model to share the system development risk.

These options will also drive the selection of how ATM data services are provided. Finally, so will the way ATM Data Services are regulated. As the benefits are realised by rationalisation, harmonisation and quicker deployment of new innovative services, ATM data services are likely to be most successful in the longer term as a contestable market – however, in the shorter term regulatory support will be needed to first define and create that market.

Realising benefits in the Physical layer

The physical layer contains radio, radars and sensors which are geographically dependent to provide all the raw data from the auxiliary services (Communications, Navigation, Surveillance, MET and AIS).

Current arrangements for these services are based on the needs of the national ANSP and are often managed by the ANSP from the ATSUs. The current arrangements do include many data sharing arrangements (particularly for radar data) and pan-European providers.

There have always been notable exceptions – particularly SITA for air-ground communications and ESSP for EGNOS Navigation Services and more recently the advent of space-based ADS-B by Aireon. These pan-European service providers point the way to the future integrated system, where a national ATSP is able to subscribe to a range of specialist services required to meet their CNS requirements (for example using SESAR's iCNS concept).

The potential benefits in the physical layer come from three mechanisms:

Step	Form of benefit	Description	Estimation method	Cost savings
Step 1	CNS Rationalisation	CNS rationalisation infrastructure by removing CNS assets, in terms of VOR and NDB.	Historical estimate from PRC.	Up to € 34 m per annum
Step 2	CNS Consolidation	Planning of CNS assets on a wider geographical scale to reduce the numbers of certain assets – optimised SSR coverage.	Estimate from CNS expert group	Up to € 22 m per annum
Step 3	CNS Deployment	A fast and simplified deployment of new CNS systems is supported.	TBD	TBD

The physical layer brings limited benefits within the traditional CNS markets but with higher potential when considering building the right network collaboration to successfully transition to iCNS and deploy new technologies. It is anticipated that the physical layer will be a relatively fragmented market with service providers at three levels:

- National – the ATSP operating physical assets retained to support local (e.g. general aviation) and military requirements;
- Regional – ATSPs collaborating to provide a regional service taking advantage of cross border coverage and frequency planning;
- Pan-European - Procurement of commonly agreed new CNS services by the Network Manager or another European body could minimise costs.

As a competitive market, entry barriers would be high. However, a contestable market could be created by outsourcing operations and maintenance but not CNS planning and asset ownership which would be kept under the ANSP/State responsibility and therefore limit the horizontal collaboration benefit.

What does the future ANS market look like?

Harmonisation not fragmentation

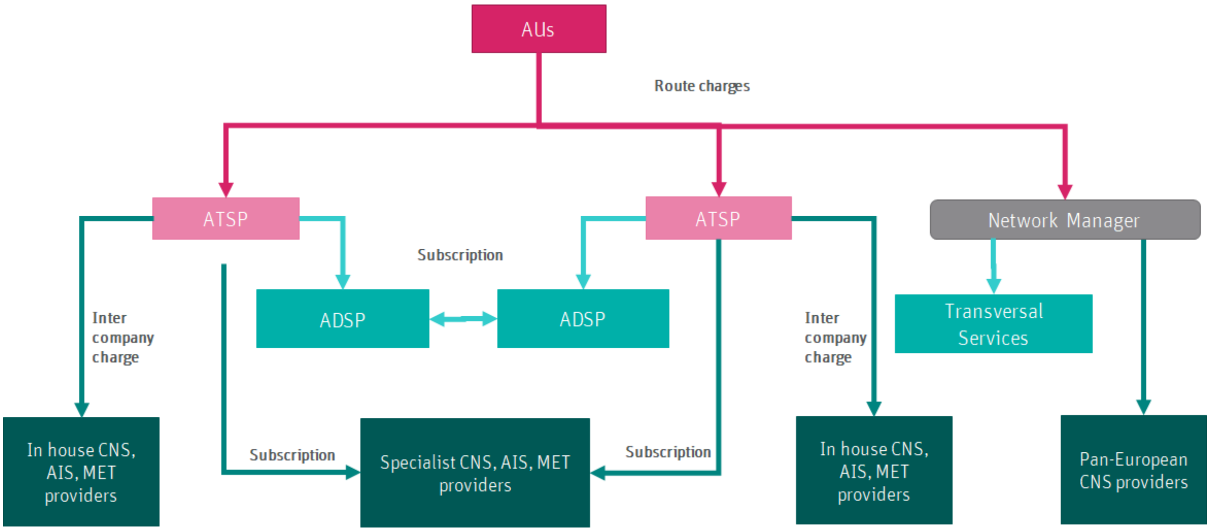
Although virtualisation is all about reducing fragmentation through harmonisation of systems, it leads to new forms of operational fragmentation: an end-to-end air traffic service currently provided by a single ANSP in the future will rely on multiple organisations across the three layers. Each new organisational interface leads to additional safety and cyber-security risks. Similar risks have been mitigated in other industries such as banking and telecoms – but as a real-time 24/7 endeavour ATM is rather unique and these new risks need to be formally assessed and mitigated.

At the heart of the issue is building trust between the providers in the different layers – requiring new approaches to standardisation and regulation. From a standards perspective it is a shift to standardising business services between providers rather than deployed equipment – a continuation of the trend started with the early adoption of SWIM services.

From a regulatory perspective, the operational approval of providers in the common data and physical layers will need to be sufficient to allow the ATS provider to use the performance and interface requirements placed on these lower layer providers within their safety cases and cyber security processes. The regulator is going to have to understand the end to end service rather than the organisational requirements of the individual providers.

Emerging organisational models

But whilst the transition does represent a technical challenge, the real issue is organisational and how to regulate new entrants. The initial decision a national ANSP faces is not the investment but the organisational model or the form of collaboration with neighbouring ANSPs in each of the three operational layers. Which in turn leads to questions on how best to incentivise "deeper" forms of collaboration that drive the real benefits.



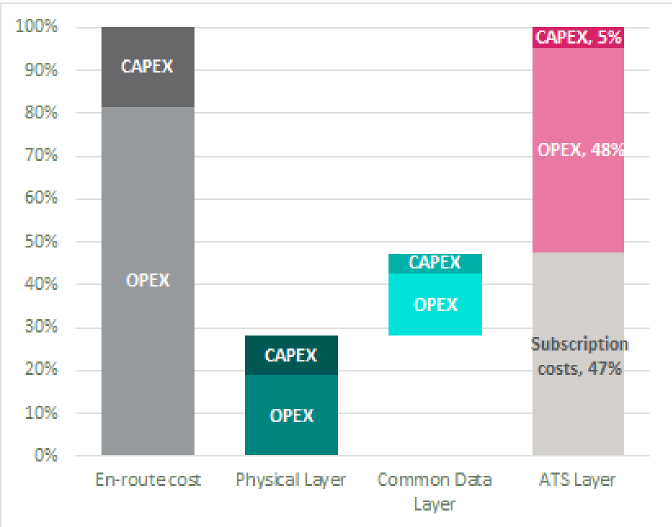
How can the transition incentivised?

Hopefully, it is now clear that virtualisation offers an opportunity to modernise ATM in Europe by enabling collaboration between national ANSPs in a way not currently achieved within FABs. The virtual centre concept enables alliances of ANSPs to gain flexibility and scalability benefits previously only considered possible by consolidation of area control centres and even ANSPs.

It has also become clear that a greater understanding of the objectives of virtualisation is required to ensure that the technical solutions developed, are capable of realising the benefits. Our analysis demonstrates that the real benefits (80% of the total) are through improvements in the ATS layer and that they are best enabled by the flexibility that the common data layer provides. The focus needs to be on building alliances and collaborations within the ATS layer to ensure that the common data layer is able to support those collaborations.

Economic Regulation

Under the Single European Sky, ANSPs operate under a form of economic regulation that fixes unit prices for a reference period with return on investment tied to the size of the regulated asset base. Traffic and risk sharing schemes reduce the risk to the service provider. If all Common Data and Physical Layer services were outsourced, then capital expenditure (CAPEX) would be reduced from 18% to just 5% whilst the overall traffic and cost risks would remain largely unchanged.



Hence, the current form of economic regulation does not incentivise the correct behaviours required to transition service delivery to the virtualisation model. Returns are based on capital employed which promotes ANSPs to increase planned capital expenditure (to increase allowed profitability) and to some degree to delay that expenditure (to increase actual profitability). Switching to a TOTEX (total expenditure) approach may be more beneficial to successfully tackle the CAPEX bias challenge by providing greater scope for making efficient CAPEX-operational expenditure (OPEX) trade-offs, as proven by other industries.

Role of competition

Introducing competition in ATM should incentivise greater performance as entities strive to sustain and grow market power/share, resulting in downward pressure on prices and increased productivity. Competition tends to create a more cost-efficient and better-quality service, as entities are encouraged to shift to a more customer-centric approach in order to attain a better reputation than competitors.

With virtualisation it is possible to envisage competition in all three layers. However, to successfully introduce competition between firms, contestability needs to be considered – low barriers to entry and limited sunk costs allowing new entities to easily exit.

Our analysis suggests that Common Data Layer would benefit from competition and to a lesser extent the Physical Layer, but in both cases a harmonised approach to outsourcing is required to ensure a coherent and contestable market.

Getting incentivisation right

Virtualisation implies significant change for national ANSPs. It is a change that has already started, in terms of Functional Airspace Block (FAB) based collaborations, regional alliance like Borealis and FDP procurement initiatives. In the age of SES and SESAR, European ANSPs talk to each other more and make more collective decisions than ever before. These collaborations need to be deeper, particularly in terms of operational concepts and ATS delegations. The distributed architecture being discussed since the publication of the AAS provides the platform for such collaborations.

What history does tell us, is that incentivisation is necessary to support changes in service provision – ATM cannot not rely on disruption from external actors. Incentivisation could include:

- Supporting the validation and initial deployment of the proposed architecture (e.g. through the SESAR programme and in particular the Digital Sky Demonstrators envisaged in SESAR3);
- Changing the performance scheme to ensure Return on Investment related to overall costs and not just CAPEX;
- Ensuring restructuring costs are not penalised when setting price caps.

Next Steps

This white paper is a high-level summary of project RoMiAD – a catalyst fund project of SESAR's Engage KTN. The intent was never to propose solutions, but rather to probe the options for virtualisation in terms of the benefits, in order to explore where further work would be most beneficial. Clearly there is still technical work to understand how the requirements of different collaboration models drive the design and organisation of the common data layer and physical layers, but the new service provision landscape means we also need to research the economics of ANS with fresh eyes, including:

- Addressing how new approaches to cost and traffic risk sharing should be reflected in the form of economic regulation.
- Considering how the cost of ATS provision should be recovered and distributed across the organisational collaborations. Does the new service provision model change the effectiveness of common route charges and charge modulation?

Glossary

ANSP	The certified provider of one of more Air Navigation Services (ANS). This is the regulatory definition of ANSP.
National ANSP	The organisation charged with the provision of ANS within a member state. This is the common usage meaning of ANSP.
Digitisation	The process of turning analogue signals into digital representations. Digitisation in ATM has been on-going for many decades but is not yet complete. Many voice-only ATCO instructions still exist, and key agreements such as the letters of agreement (LoA) between ACCs are not digitised.
Digitalisation	The transformative process of organisations taking advantage of digital technology. ATM is only scratching the surface of digitalisation. The AAS proposes one specific form.
Virtualisation	The specific form of digitalisation proposed by the AAS whereby organisational collaborations exist at the ATS, Common Data and Physical Layers mediated by digital infrastructure (and transversal services).
ATS Layer	The layer of the AAS where Air Traffic Services are provided.
ATSP/ATSU	ATS is provided by the ATSP from one or more ATS Units. ATSU can be ACC or terminal control (TC) or airport towers.
Common Data Layer	The layer of the AAS where ATM Data Service are provided. The Common Data Layer allows for greater interoperability and harmonisation by ensuing timely and accurate data is available to all stakeholders.
ATM Data Service	The services provided by ATM Data Service Providers (ADSPs) operating in the common data layer.
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.
Virtual Centre	A collaboration of ATSUs in the ATS Layer. A Virtual Centre (VC) consumes services of ADSPs operating in a common data layer. Whilst the nature of the collaboration within the VC depends on organisational and technology choices, in theory a VC operates seamlessly as if it was one physical location.
Virtual Data Centre	A collaboration of one or more ADSPs to ensure data availability for all VCs served.
ATM System	The ATM system is the technical infrastructure within the current ATSU, traditionally comprising CWP, Flight Data Processing system (FDP), Surveillance Data Processing system (SDP), Voice Communication (and) Control System (VCCS) and numerous other systems that support the Air Traffic Controllers.

OUR EXPERTISE

- Trajectory Based Operations
- Remote and Digital Tower
- Wake and Time Based Separation
- Airport CDM
- Performance Based Navigation
- Flexible Use of Airspace
- Unmanned Aerial Systems
- Runway Optimisation
- Virtual Centres
- Enterprise and Airspace Architecture
- ATCO Team Organisation & Training
- Airspace Change
- User Driven Prioritisation Process
- Controller Tools
- Sequencing Tools
- Airport Safety Nets

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