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STWG EMERGING TECHNOLOGIES WHITE PAPER -VIRTUALISATION

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Virtualisation

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1.1 General Description

Consider an environment where services are provided in a digital manner that decouples the location of the infrastructure from ATS service delivery; this situation corresponds, in technical terms, to a virtualisation of service provision.

Virtualisation from a technical perspective refers to a different use of resources, with new enablers such as data centres.

In air traffic management (ATM), virtualisation is addressing different operational objectives and use cases. It has a role in enhancing the resilience of operations, contingency for abnormal operations, remote operations for load sharing (scalability) and most importantly, enabling cross border delegation of air traffic services by providing "capacity on demand" supported by virtual centres.

1.2 Background Information

At the ICAO Air Navigation Conference (ANCONF/13) in 2018, Remotely Operated Aerodrome Air Traffic Services also known as "Remote Towers" were introduced in the ICAO ASBU FRAMEWORK (RATS-B1/1) and with more details in the SESAR solutions catalogue 2019 (third edition) aiming at ensuring service provision, even for a limited time, in remote locations for low traffic aerodromes.

Virtualisation is supported by digitalisation of information and for ATM is greatly facilitated by the System-Wide Information Management (SWIM) concept and service-oriented architecture (SOA). In this way, an incremental migration from the current ATM system to an Open ATM architecture is facilitated.

Flexible access to the relevant assets supports a dynamic response to various contingencies, including equipment or facility outages, dynamic airspace reconfiguration, or business continuity planning operations. The following operational use cases are considered:

• **Business Continuity:** Overcome availability restrictions at one facility by other facilities taking over the affected airspace.

- Load Balancing: Handle increasing air traffic load at one location by other controllers, independent from their location anywhere in the country.
- Virtual Towers (aka Digital Towers): Control digitally the air traffic movements on and around an airport.
- Reduced reliance on 'brick and mortar' facilities by increasing the digital footprint when replacing old facilities and minimising the addition of new facilities.

These operations lead, in turn, to a better balance of air traffic controller workload and more efficient use of the airspace. As a result, further increased safety, decreased delays and traffic congestion, as well as higher flexibility in handling air traffic can be expected.

1.3 Concept

In examining virtualisation in ATM, this paper will explore available implementations today as well as future concepts i.e., what could be achieved by implementing virtualisation to a maximum extent.

- Today, air navigation service providers (ANSPs) are collecting data themselves (e.g. via radar installations) or from third parties (e.g. meteorological information). ANSPs are processing that data internally and providing an air navigation service (ANS) to the airspace users. In this way, ANSPs are acting today as ATM Data Service Provider (ADSP) and as Air Traffic Service Providers (ATSPs) which is composed of a series of Air Traffic Services Units (ATSUs) where Air Traffic Controllers (ATCOs) are working. Virtualisation is achieved by providing the services independent from the location of the infrastructure, e.g. remote tower deployments.
- The future concept of virtualisation is associated with the provision of data services via providers that are decoupled organisationally and/or physically from the entity producing the data and the final user (the ATCO working in the ATSU). Virtualisation is therefore not only about separation of location of the infrastructure and provisioning of the service, but also the potential separation at an organisational level.

1.3 Concept (continued)

Furthermore, a future ATM service could be envisaged as a composition of services (data provision for each single data type like flight tracks, flight plans, conflict detection...) with different granularity in a cloud infrastructure with features like high availability, fault tolerance and reliability.

At the time of writing this draft, different options in cloud infrastructure management and ownership were identified:

- Manage an external/public cloud infrastructure via external providers within a market perspective. In this case the provider opts to concentrate on the service development and outsources all the maintenance to the solution provider. It may not be a very suitable choice for ANSPs for safety and security considerations due to potential performance limitations in Service Level Agreements (SLA). Some legislation may not allow data sharing in a different country (for security/ safety reason). This happens in many fields, not only in the ATM domain. For example, a country flight data/radar data may not be allowed to be stored in a third country database.
- A local/private cloud infrastructure managed by an ANSP that provides the service. In this case the configuration and maintenance of the cloud infrastructure is managed by the ANSP itself.
- A hybrid environment that uses a mix of local and external cloud infrastructure where the providers fulfils the operative/ security requirements.

As an example of data service provision, some ANSPs receive Automatic Dependent Surveillance–Broadcast (Space Based ADS-B) tracking data through Aireon – a global surveillance service provider. The service provides ANSPs with a high-fidelity, low-latency source of positioning data within or far beyond their own Flight Information Region (FIR) or Area of Responsibility (AoR) without the need to sign data-sharing agreements with neighbouring countries. Operationally both concepts of virtualisation are associated with the operational use cases mentioned in 1.2 above, enabling the provision of Air Traffic Services (ATS) independent from the location of the infrastructure. In this context of 'capacity-on-demand', the following operational scenarios are considered:

- Delegation of ATS for a specific block of airspace depending on traffic load: shared controller resources between different ATSU facilities or different ATSUs to handle high or low traffic times.
- Delegation of ATS for a specific block of airspace in case of failure: providing service continuity in case of reduced/missing capacity due to equipment or facility outages.
- Optimisation and flexibility of resource utilisation for tower operations: optimise controller resources for towers with low traffic volumes.

Looking at virtualisation from a technical viewpoint, the hardware and software providing the applications to the ATCOs are completely separated from the location where the service is provided. It can be in the same building, or equally it can be thousands of kilometres away or anything in between. The software could be architectured on a cloud infrastructure when adapted to the various requirements.



1.3 Concept (continued)

The basis for this implementation is the IT technology which we all use in our daily life. We are used to experiencing the same communication, chat or location services independent from our exact location. We also access the sensors of our smart home from around the world. Deploying these technologies in ATM enables the segregation of the devices hosting the applications from the location where the services are provided to the airspace users. Quite a number of examples are already deployed around the world:

- In the case of Remote and Virtual Towers, ATCOs at one location can provide a service to airspace users at one or several airports (at different locations) supported by software applications hosted in data centres at another location, collecting the data from sensors at the airports (e.g. cameras) or other locations. All locations must be interconnected via reliable and secure IP infrastructure in order to share the different types of data between the locations. The required wide area network IP infrastructure may be rented from a national carrier with a suitable service level agreement in place or set up by the ANSP itself. Whatever the chosen solution, the requirement is to ensure a resilient communications network able to be manageable in terms of availability, integrity and quality of service.
- In the case of virtual centres, the ATCOs at one location would provide their service to airspace users in one or several sectors in their own or another country supported by software applications hosted at data centres at the same or different location, collecting the data from sensors somewhere in the country. Also in this case, all locations would be interconnected via reliable and secure IP infrastructure hosted by a national carrier or the ANSP itself but ensuring a communications service able to offer trust enough to the end users through the appropriate mechanisms.
- Note: Trust should be based on some evidence of control capability of the network.

In addition, for the future organisational approach where ATM data collection and processing is decoupled from ATC centres, the technical concept would remain the same while different organisations would take care of data collection/distribution on the one side and data processing on the other side. This would lead to additional security and interoperability considerations at the border of the different networks in order to ensure data integrity and consistency, e.g. introduction of several layers of firewalls and Session Border Controllers at the network borders.



The following figure illustrates the main features of Virtualisation in the context of Tower and ACC Control Room.

Figure 1 – Main features of virtualisation of ATS

Note: the SWIM services are mentioned here as key enablers for operational interoperability of virtual centres.

1.3 Concept (continued)

Virtual centres and remote towers generally lead ANSPs to reinforce two distinct topics:

- Cybersecurity activities: the extensive use of wide area network (WAN), of public and private clouds leads ANSP to put in place permanent cybersecurity risk assessment and appropriate tools to manage the vulnerabilities. Thus, a dedicated organisation with new systems to detect and handle miscellaneous cases of cyber-attacks has to be considered. At the same time, the virtual centres, based on more and more standardised interfaces, will benefit from new technologies and COTS (Commercial off-the-Shelf) products, subject to continuous cybersecurity vulnerability vigilance.
- Safety activities: Without a doubt, virtual centres pave the way for increased resilience and stability with multiple sources of data and locations for operations. Nevertheless, an end-to-end safety assessment of the architecture and the operational procedures will likely show new potential weak points to be addressed with the highest consideration to find the appropriate answer from a safety point of view. Two examples of new points of attention:
 - The safety of the network (between data centres and virtual centres) and all equipment supporting it is now leading to new analysis and solutions for keeping the highest level of safety in ATC, considering generally applied standards in Europe for software assurance (ED153, ED109A)
 - The possibility in a virtual centre to collect and merge ATM data (Air Traffic Data Services) from distant and different data centres leads to new analysis of the processing for merging information (which is essential for ATCOs focusing on track labels) and avoiding critical data corruption.

In both cases, ANSP should expect impacts on virtual centres on procurement, engineering, operational and training activities.

From the point of view of platform infrastructure it is necessary to develop new capacity to provide the requested services. These services could be built with different approaches for example based on software and middleware (SWIM services) or over infrastructural services (remote display).



Maturity Level

2.1 R&D Initiatives

2.1.1 SESAR programme

Research and development for Remote and Virtual Towers started in the early 2000s in research programmes like SESAR in Europe. As a result, SESAR promoted Remote & Virtual Towers as "solutions" ready for implementation in 2017 while the first digital tower implementation providing aerodrome ATS based fully in accordance with ICAO documents Doc 4444 and Doc 9426, was approved into operation in Sweden in April 2015.

Efforts to update the ICAO ASBUs developed in parallel and remote and virtual towers are now present in the ICAO Global Air Navigation Plan (GANP) in the thread RATS for Remotely Operated Aerodrome Air Traffic Services (RATS-B1/1).

SESAR programme continues through SESAR2020 with research on Remote Tower Centres and flexible allocation of aerodromes.

For Virtualisation of ATM service provision, (Virtual Centres) SESAR projects (in particular work on Service Interface definition of the Controller Workstation in 2014) initiated work to explore the virtualisation of ATM data services to the Controller Working Positions (CWPs) gathered in an ATS unit. Other SESAR Projects have been launched since 2017 in the context of SESAR 2020 programme to investigate several technical and operational aspects including the validation of a virtual centre for en-route national and cross-border operations.

2.1.2 NAV CANADA

Saint John, New Brunswick Trial - The purpose of the trial is to obtain approval from the regulator, Transport Canada, by demonstrating that the advisory service, delivered remotely and digitally by high-definition cameras, can be achieved in compliance with all current regulations in a single mode operation. The remote service will be made available from the Saint John FSS when the Fredericton Tower is closed during the overnight hours. The airport serves mainly scheduled airlines and flight training units. The architectural pattern followed by the Saint John trial is aligned with the remote digital tower model where the sensors, digital control room and data processors are not all located at the Fredericton airport. Rather, the camera sensors are located at the airport in a configuration which supports a 210-degree view of the airport surroundings but the digital control room and supporting data processors are located in Saint John. The trial was successfully concluded and accepted by Transport Canada in June 2021.

Red Deer, Alberta Trial - The purpose of the trial is to obtain approval from the regulator, Transport Canada, by demonstrating that the air traffic control service, delivered on-site yet digitally by hi-def cameras, can be achieved in compliance with all current regulations in a single mode operation. The virtual control service is expected to be made available 16 hours per day. The airport serves mainly small airplane operators such as flight training schools and private operators.

The architectural pattern followed by the Red Deer trial is aligned with the proximate digital Tower model where the camera sensors that provide a 360 degree view of the airport surroundings, the digital control room and data processors are all co-located at the Red Deer airport.

2.1.3 Skyguide

The Swiss civil and military air navigation services provider skyguide is role-modelling the implementation of the virtual centre concept in Europe. In a vast programme defined in three distinct tranches, skyguide is transforming the operational environment to allow for service-based architectures.

The skyguide virtual centre programme was set up in three distinct phases starting in 2014. The first two phases will have been completed in 2021 with the third phase spanning 2022-2025.

In very little time, skyguide has leap-frogged the progress and is now relying on a widespread market Commercial off the Shelf (COTS) solution for the SOA backbone. More details on the current and on-going implementation is provided at section 3.3.2.5.4.

Maturity Level

2.2 Industrial Product Development

Virtualisation of towers is fully mature with several ANSPs already benefitting from such implementation in terms of safety and cost-efficiency for remote areas. Details, including operational experiences, are described in the document CANSO Guidance Material for Remote and Digital Towers.

The virtualisation of centres concept has reached a stage of development which can be considered mature, at least from a single ANSP point of view. Different projects around the world have been realised or are currently in the final stage of realization, benefiting soon from better balance of air traffic controller workloads, more efficient use of the airspace, increased safety, decreased delays and traffic congestion as well as higher flexibility in handling air traffic. The next step of providing infrastructure services is being prepared.

In general, all needed technologies are in place and available today to complete the transition away from the traditional hardware-oriented technologies towards software only solutions running on servers in high available data centres connected with other servers, clients or sensors over a secure and high reliable IP network. Especially with the completion of the development of the remote tower concepts with their visual views and presentations to the controllers extended with first implementations of artificial intelligence, the last major milestone has been completed and proved its operational readiness. Of course, the technology will evolve further and will develop as needed through operational deployments or requirements by new national or international regulations (e.g. how the ANSPs have to secure their infrastructure or how artificial intelligence can improve processes and make operation even safer).

What seems to be more challenging is the operational and organisational readiness of the ANSPs. Introducing concepts like remote tower and virtual centre requires adaptations in the organisations with respect to responsibilities and procedures in order to ensure a safe navigation of air traffic independent from the controller's location. Another organisational challenge will be the decoupling of ATSU and ADSP. Standardisation activities are conducted to support industrial product development and it is important to note the following EUROCAE work:

- EUROCAE established WG-100 Remote & Virtual Towers" in 2014 and published ED-240A Minimum Aviation System Performance Standards (MASPS) for Remote Tower Optical Systems in October 2018. WG-100 is continuing work to develop ED-240B which would include requirements for non-optical sensors.
- EUROCAE established WG-122 "Virtual Centre" in 2020 with a view to supporting the industrialisation of one of the Essential Operational Changes from the European ATM Master Plan (ed.2020) for the Digital European Sky.



3.1 Other Industries

Other industries such as the banking industry have undertaken a transition to a service-oriented architecture (SOA) to address virtualisation. The relevance for ATM on the approach in the example of the banking industry is the desire to ensure interoperability without requiring uniformity (i.e. one "fit for all" solution). This means, taking care of the operations to be digitalised and to do it based on a harmonised way to serve particular needs.

The initiative named the Banking industry architecture network (BIAN) is, as stated in the site www.bian.org "a collaborative not-for-profit ecosystem formed of leading banks, technology providers, consultants and academics from all over the globe (...) to define a revolutionary banking technology framework that standardises and simplifies core banking architecture, which has typically been convoluted and outdated." Based on SOA principles, the comprehensive model provides a future-proofed solution for banks that fosters industry collaboration.

It was "created to establish, promote and provide a common framework for banking interoperability issues and to become and to be recognized as a world-class reference point for interoperability in the banking industry". It aims to be "a main contributor to the knowledge and services needed to facilitate and implement banking interoperability in order to develop and operate a community assisting user organisations with platform and services", constituting a common architectural framework.

The lessons learnt of the BIAN initiative are:

- Need for interoperability
- Need to focus on the business services
- One size does not fit all

3.2 Potential Application for Aviation Industry

As already elaborated, the ANSPs will take most advantage of virtualisation with the possibility to realise new operational concepts such as remote towers or virtual centres, allowing them to benefit from reduced capital expenditure (CAPEX) and operational expenditure (OPEX).

To manage airline operations, virtualisation of service provision can be seen in the Flight Operation Centre where airline officers can interact both with each crew and with all the stakeholders involved, e.g., meteorological (MET) service providers, Airport Authorities, ANSPs, NSAs. In addition, flight management services for general aviation will benefit from virtualisation in a similar way as the ANSPs with the virtual centres.

Having said this, virtualisation can become the basis for a large range of ATM related services. Virtualisation will play a future role in other areas, such as unmanned traffic management (UTM) and advanced air mobility (AAM).

Finally, completely new business areas are imaginable:

- Pure data service provider: installing sensors, collecting data and providing them to the ANSPs or any other organisation, e.g. for weather, surveillance, geographic information and flight information,
- ATM cloud provider: hosting the collected data and sharing them with the ATSUs or any other organisation, or
- Completely new ATM services might be developed in future with easy access to all data combined with automation or Artificial Intelligence.

3.3 Potential Application for ATM/ANSPs

The national provision of ANS is based on local implementation of the necessary capabilities. While this was technically the most feasible and appropriate solution when systems were originally built decades ago, this fragmentation of service provision generates cost-inefficiencies and a rigidity that makes it impossible to properly address the capacity challenges of today and tomorrow. Modern-day general-purpose communication and computer processing capabilities allow for better performing and more cost-efficient solutions, where physical processing capabilities no longer need to be close to the point of use. A reorganisation of physical assets among ANSPs, civil and military, should lead to facilitated data sharing, new synergies and more cost-efficient management of the ATM resource network. It should also facilitate effective interoperability between functional systems. With the support of virtual-centre technologies, it will be possible to provide services to one or more FIRs that may or may not be adjacent to each other, thus increasing the resilience, adaptability and scalability of the network with a view to delivering more capacity and cost efficiency.

The ability to provide ATS from a remote location is relevant in all operating environments: airport, terminal or en route. In terminal manoeuvring areas (TMA), extended TMA and en-route environments, the virtual-centre concept allows a geographical sector to be managed from any place subject to the availability of some services crucial for the provision of ATS, namely communication, navigation and surveillance (CNS) services, MET, aeronautical information services (AIS) and all data related to the flight plan. By using standardised operating methods, procedures and technical equipment, the services will be perceived as a single system from the user's perspective. This will be enabled by cloud-based data centres as well as data management processes and governance, provided remotely. More details can be found in the CANSO Guidance Material for Remote and Digital Towers published in 2021.

For each application, safety and security must be assessed at each step, locally and end-to-end. The aggregation of data of variable quality is raising new safety and security concerns and must be addressed.



3.3.1 Field of Application - Remote Towers

3.3.1.1 Description

The Digital Tower concept is enabling the provision of aerodrome (ATS) from any location¹. Digital Tower technologies provide a view of the aerodrome and its vicinity, enabling operators to conduct visual surveillance using digital means rather than relying on the view provided from the visual control room using the naked eye and binoculars. The Digital Tower concept encompasses a range of operating modes and applications applied using varied technologies.

- Single mode operations refers to the provision of an aerodrome ATS to one airport from a Digital Tower. Services provided will include all forms of ATS and rely on a suitable operational team of one or more operators as required to maintain safe operations. This mode commonly refers to the full-time provision of ATS from a permanent digital tower facility, where a conventional tower is not used. This is to be inclusive of all variations of single mode operations e.g. Single Switch mode where an ATCO can operate more than one airport per shift but only one at any time.
- Contingency mode operations refers to the provision of aerodrome ATS in cases where the permanent ATS facility is unusable, e.g. in nonnominal or business continuity events. As such the technical solution is not proposed as a permanent replacement to the conventional tower, which will still be the primary facility for ATS provision. Contingency mode operations can be provided from a permanent digital tower facility or a temporary facility. Temporary facilities may not have the same certification requirements.



 Multiple mode operations – refers to the provision of aerodrome ATS to two or more aerodromes simultaneously from a digital tower. As such, this reflects a significant change to current conventional operating methods. The use of digital tower technologies within a conventional tower can enable previously unavailable, innovative ways to display information to operators. They can also enable the aerodrome ATS function to be better connected to other ATS and aerodrome functions, for example connections to airport operations centres or area control centres, and this, in turn, can enhance information sharing and facilitate a range of performance benefits.

3.3.1.2 Benefits

Remote towers and the associated technologies can be implemented to bring about a range of social and economic benefits for a variety of stakeholders. Benefits depend on the specific modes of operation and the implementation environment. Key benefits enabled by remote tower concepts are listed below:

- · Improvements in cost-efficiency;
- Flexibility, enhanced level of service provision and availability regarding when an ATS is provided (user-focused service provision) and where it can be provided to or from (removing physical restrictions);
- · Improved operational resilience;
- · Improved contingency and crisis management;
- Enhanced service delivery and performance or safety;
- Centralisation of service and information availability;
- Stakeholder benefits, for example the positive impact on AUs and airport fees.

¹ For more information on Digital Towers consult CANSO Guidance Material for Remote and Digital Towers.

3.3.1.3 Challenges

The challenges faced by digital tower programmes are specific to the operation and organisation. Some of the common challenges identified from the lessons learnt of early adopters are discussed here.

- Stakeholder acceptance regarding change of environment, roles and tools as well as increased possibility of workforce reduction that requires a change management approach;
- Regulatory approval is a challenge as a result of the uniqueness of each solution and the need to ensure compliance;
- Difficulty in defining and generating clear evidence for decision makers on a business case due to the current high costs of entry and the required customisation;
- Limited global up take to date and lack of standardisation and uniformity in the associated technologies. This is a challenge for early movers;
- Infrastructural and technological limitations (e.g. latency) which vary depending on the case study;
- Operational resource availability and experience constraints.

3.3.1.4 What is next for Remote and Digital Towers?

There are three main areas that require attention to develop remote and digital towers in the future:

- Future Technology Concepts: It is important that digital tower solutions are scalable for future technology. Technology and concepts that are still in development but which have the potential to provide benefits to digital and conventional tower operations, are primarily concerned with the ability to:
 - Integrate and share more useful data to aid the aerodrome ATS service provision, the airport operations and the wider ATM network;
 - Enhance performance in a specific area;

- Provide advanced conflict detection and forecasting/visualizing;
- · Visualise information in novel ways; and,
- Provide more integration of the digital tower with other ATS systems through one human machine interface.

Such advanced technology is thought to be of greater importance when operating in certain, often more complex, operational environment or if ANSPs are targeting specific performance improvements. These technologies are those which may enable a more automated, proactive, and connected operations i.e. smart tower concepts. This next phase of the digital tower concept looks to enhance aerodrome ATS and increase the integration between the tower and the rest of the ATM network. This may include increased information sharing and coordination with other ATS functions (approach and area services), with other functions of the airport and with other airports.

- Large scale Digital Tower Centre: Digital tower centres providing aerodrome ATS together with other ATS (approach and area services) may be seen more in the future. Such large-scale operations enable a range of performance and efficiency benefits. Challenges and differences will also arise from large scale digital tower operations, mainly on roles and responsibilities, training and coordination and responsibilities. Note: such a Large Scale Digital Tower Centre is already in operation in Norway where the Bodo RTC opened in October 2020).
- ATM and UTM Integration: Digital tower technologies may be used to help to accommodate a growing unmanned aircraft system (UAS) presence. Leading to potential safety improvements and information sharing improve safety, which in turn may help this form of traffic to integrate with more traditional forms of air transport.

3.3.1.5 Examples

3.3.1.5.1 LFV in Sweden

LFV was the first ANSP in the world to provide aerodrome control services remotely in April 2015, from a RTC in Sundsvall, using a digital tower system. Currently four Swedish regional airports are provided with remote aerodrome ATS from that RTC.

Another RTC, 'RTC Stockholm', is being deployed in connection to the LFV ATCC at Stockholm Arlanda airport. The initial plan is to provide remote aerodrome ATS to four Swedavia (state airport operator) airports from RTC Stockholm. The first airport to be connected to RTC Stockholm (Kiruna) is expected to become operational in 2021. LFV will be the ATS provider for RTC Stockholm.

3.3.1.5.2 AVINOR Remote Towers Centre in Norway

Four airport towers are operational at the Avinor RTC in Norway: The towers at Røst, Vardø Hasvik and Berlevåg airports are operated from the Avinor Remote Towers Centre in Bodø, Norway – north of the Arctic Circle.

The formal transition process of the tower services at Hasvik and Berlevåg airports to the Remote Towers Centre were both completed in the same day, in close coordination between Avinor Air Navigation Services and the Norwegian Civil Aviation Authority.

The tower at Røst airport was the first to go operational from the Avinor Remote Towers Centre in 2019. The tower services at Mehamn and Røros are the next in line to be transitioned to the Remote Towers Centre. The new Remote Towers Centre building in Bodø was officially opened in October 2020 and will operate tower services at a total of 15 airports by the end of 2022 (phase 1). This is the world's largest Remote Towers Centre.

3.3.1.5.3 DFS Remote Tower Control (RTC) in Germany

DFS Deutsche Flugsicherung, the German ANSP, has developed an advanced remote tower solution for the three international airports Saarbrücken, Erfurt and Dresden. In December 2018, the remote tower solution went into regular operations for Saarbrücken International Airport, which has 15,000 flight movements per year. The other two airports will be phased into the Remote Tower Control Centre in Leipzig step by step.

3.3.2 Field of Application - Virtual Centre within the same ANSP

The SESAR definition of virtual centre is as follows:

A virtual centre is a single Air Traffic Service Unit (ATSU) or a grouping of collaborative ATSUs using data services provided by ATM Data Service Provider (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.²

In this concept, virtualisation is characterised by

- The organisational/architectural distinction between ATS units with the ATCOs as consumers of the services and ATM data service provision, i.e. a data centre providing services
- Potential geographical distinction between data centres and control rooms
- Data exchanges are organised (and standardised) as SWIM services
- Potential scalability and resilience via adaptive connections N data centres connected to M ATSUs.

² https://www.atmmasterplan.eu/data/sesar_solutions/20431835

3.3.2 Field of Application - Virtual Centre within the same ANSP (continued)

Considering this particular field of application, SWIM appears as an enabler but not a pre-requisite. All data exchanges can be (are being in some cases) implemented in a proprietary way as a fast method to achieve the necessary connectivity. But as highlighted as a conclusion in the CANSO Emerging Technologies SWIM White Paper the "digitisation and the automation of some routine human processes enabled by SWIM is essential, however SWIM can be complex and there are many challenges holding back its adoption and delaying the vision of global interoperability for aviation". The lack of standardisation and of the products in the market allied to lack of maturity of the organisations to change to a SOA has to be considered in a small step approach, which is possible in this scenario.

3.3.2.1 Description

The figure below describes a solution for different locations of ATSUs/virtual centres for the same airspace within the same ANSP.



Figure 2 – Possible infrastructure with data centres and virtual centres within the same ANSP

- One or more data centres provide ATM data to the ATSUs
- ATM data services can be preferably based on standard interface (but one ANSP can implement without waiting for standards)
- · Remote operations can be in the same country as data centre or not
- Local information which can be shared from the ATSUs to the data centres are:
 - Local surveillance information (e.g., the APP is using a local radar)
 - Local Aeronautical Information (e.g., runway in use changed by the ATSU)
 - · Local sectorisation information (e.g., grouping at night)

3.3.2.2 Benefits

The implementation can be incremental with a mix of local and virtual organisations, addressing issues one at a time (staffing, licensing, infrastructure...)

Note that sites #1 and #2 in Figure 2 could be interchangeable and provide business continuity enhancements.

The main benefits from such virtual centres architecture (possibly combined with local infrastructure) are listed in the table below.

Туре	Benefit
Business	 Increased ability of the centres to provide contingency for each other leading to high resilience and enabling business continuity
	 Lower service provision costs by potential outsourcing of data services and rationalisation of auxiliary services
	 Achieving benefits whilst maintaining the current locations, therefore reducing issues around staffing and politics. Potential improved sustainability as a result of rationalisation of infrastructure.
Technical	 Breakup silos of each ATM application by installing service oriented, open and modular architecture, which allows to interconnect with other ATM applications via standard APIs
	Integration and consolidation of critical data
	\cdot Potential benefit of agile development of ATM applications and improvements
Operational	 High flexibility by faster reaction in case of ramping up or reducing ATCOs following unexpected traffic change (dynamic allocation of airspace)
	 Possibility to not only optimise the work of a single ACC, but the complete infrastructure within an ANSP
	 Reduce buffers for capacity of each single ACC and address capacity issues from a complete infrastructure perspective
	 Load balancing between sites, avoiding capacity issues or to reduce weekend/night work at one ATSU location
	 Increased ability to perform capacity demand balancing across centres within the same ANSP

Table 1 - Benefits of Virtual Centres within the same ANSP

3.3.2.3 Impact

Such virtual centre impacts:

- ATCOs and ATSEPs, organisation and training
- Day to day operations with less handovers between centres
- Need for synchronisation and alignment between ATSUs
- Global ATM architecture including voice communication systems, sensors local information sharing with cybersecurity concerns
- Interoperability of two ADSPs

3.3.2.4 Challenges

The challenges which have to be considered by ANSPs and other stakeholders are outlined below.

Туре	Challenge
Political Regulatory	 Potential dilution of responsibility (legal, technical, etc.) between the Data Centres and the Virtual Centres if the legal entity is different
	\cdot High availability or geographic redundancy of the data centre needs to be considered
	 More complex safety evaluation by the ANSP and regulator due to removing of the silos but sharing data and responsibilities
Business	 Organisational transformation including liability aspects e.g. SLAs between data centres and ATSP
	 Clarity needed over the reasoning for service continuity requirements (why such a level associated with which impact)
Technical	 Consolidation of critical data to guarantee consistency, integrity and safety of displayed information in all sites
	 Additional technical activities (networks equipment, safety, cyber security, interoperability, data consistency) between all sites
Operational	As required alignment of operational procedures of the ATCOs
	ATSEP acceptability on their changing remits and tasks
Staff	\cdot Operational and technical trainings on different sites for the same roles & responsibilities
	Less highly specialist for each individual ATM systems needed
	Manage social aspects

Table 2 - Challenges of Virtual Centres within the same ANSP

3.3.2.5 Examples

3.3.2.5.1 ROMATSA

During COVID-19 pandemic, the need to separate teams of ATCOs triggered an unexpected use case in ROMATSA: the different teams were operating in different centres to avoid contamination.

From its inception until the year 2001 the ATC services were provided from 5 ACCs with different geographical positions however all under the same BUCHAREST FIR. Gradually, along a 10year period, ROMATSA consolidated the five service points into one single centre. In 1996 ROMATSA commissioned its consolidated communication infrastructure which became the foundation for all subsequent developments. The "foundation" provides intrinsic redundancy.

During the era when ROMATSA used more than one ACC, all these centres acted from the airspace users and peer ANSPs perspective as one "virtual centre".

Since 2012 ROMATSA is operating one ACC and two contingency centres. The first Contingency Centre (CR1) is located on the same premises with the ACC and has proven to be useful for scenarios where the ACC room has been rendered impracticable during the COVID-19 crisis. The second Contingency Centre (CR2) is located in a military bunker at a remote site (~15 km distance).



AEROTHAI Suvarnabhumi Air Traffic Control Centre

3.3.2.5.2 AEROTHAI

As a Virtual Centre concept, the AEROTHAI ATM System is quite aligned on the benefits of centralising the data processing, servers, external interfaces, etc. and having a single source of truth. The system is operational since the beginning of 2020.

Main benefit: The architecture is resilient through redundant (alternate path) WAN connections.

- There is one en-route centre with 5 approach centres and 42 remote towers.
- ACC houses the equipment rooms for all servers including flight plan servers, short & long-term conflict servers, datalink servers detection, etc.
- Remote sites connect to the main ACC for reception of centrally processed data including flight plans, tracks, alerts, etc.
- At each site, a local radar is connected back to the main ACC for inclusion in multi radar processing. That local radar is also connected to the ATC system at the site as a local bypass radar. The system also runs a partition Flight Data Processing and local Flight Data Processing's at each site. Therefore, if the WAN connection fails, the system will switch automatically to the partition Flight Data Processing and the local radar feed as bypass.
- To reconnect with the ACC, it is a manual and scheduled action.

3.3.2.5.3 Ireland (IAA)

The COOPANS system installed in Ireland enabled the possibility of Virtual Centre between Shannon and Dublin.

IAA used it for a period several years ago whereby the CWP in the Dublin OPS Room was connected to the Shannon ONL system. IAA used this position to conduct Shannon Approach Control.

Expected benefits: IAA did have a belief that Dublin would be a big "Terminal unit" providing the Approaches to Shannon and Cork as well as Dublin and the same controllers could be used for Dublin Tower etc.

IAA ceased the operation of Shannon in Dublin mainly because of staffing issues (training and licensing issues).

3.3.2.5.4 Switzerland (skyguide)

The Swiss Civil and Military Air Navigation Services provider skyguide is role modelling the implementation of the virtual centre concept in Europe. In a vast programme defined in three distinct tranches, skyguide is transforming the operational environment to allow for service-based architectures.

Virtualisation of a number of ATM systems including safety critical systems

Skyguide has successfully implemented the SOA and currently operates various services, of which some are safety critical. The skyguide virtual centre programme is set up in three distinct phases.

The **First phase** from 2014 to 2017 allowed developing and deploying one harmonised solution for both Geneva and Zurich. In this first phase, standardised and harmonised processes and procedures between ACC East and ACC West were implemented. This phase also significantly increased capacity as planned and brings recurrent financial benefits.

The **Second phase** that is now closing aims at laying the foundations for location-independent operations. As a result, the New Route Handling (NRH) concept will be up and running Swiss wide (and serves as a precursor of the Free Route Airspace) and the two physical data centres from Zurich and Geneva will be merged into one single data centre based on an open architecture. This phase will bring considerable cost reductions in engineering by switching off legacy systems and operating an open, flexible and networkcentric system out of a single virtual data centre. The financial return on investment is ramping up from 2022 to 2025.

The **Third phase** will change the way air traffic controllers interact with the flight trajectories displayed on their screens. Based on the definition study and high-level plan defined in 2020, a concrete implementation roadmap has now been developed and approved. It outlines the plan to harvest the operational benefits based on the technological foundation of the second phase. This final phase is expected to bring simplified, location-independent procedures and processes together with increased automation and dynamic airspace management. In financial terms, the identified potentials are expected to bring additional savings.

All skyguide services are operating with open and universal Message exchange system. The SOA provides natively all tools fundamental to realize a proper cyber secure environment and guarantees the same continuity, availability and integrity requirements as a vertical system.

Remote data processing for virtual ATM centre

Skyguide is cooperating with the French ANSP (DSNA) in order to receive Flight Plan data from DSNA as ATM Data Service Provider (ADSP) while skyguide accordingly will act as Air Traffic Service Units (ATSU) for both Swiss Air Traffic Control Centres.

Trying to outsource the middle layer of the service who oversee the data

Skyguide is counting on external services in three major domains related to its ATM environment:

- The new virtualisation HW infrastructure is on lease and remotely monitored from Bulgaria.
 Appropriate processes to integrate this remote support have been established to integrate it into the overall technical support services delivered by the skyguide technical department.
- The monitoring management of the Enterprise Service Bus is done through remote support services in order to ensure the best level of services.
- As mentioned above, the necessary initial elements (planned to be operational by 2025) have been defined to establish the interface with DSNA to receive the flight data (hosted in Paris).

3.3.3 Field of Application Virtual Centre with cross-border operations

3.3.3.1 Description

Figure 3 describes a solution for different locations of ATSUs/virtual centres for the different airspaces in different countries.



Figure 3 – Possible infrastructure with data centres and virtual centres with 2 ANSPs

Note: The main organisational difference is conveyed by the green arrow implying the need for an airspace agreement and a concept of operations applicable cross-border.

- One or more data centres provide ATM data to the ATSUs
- ATM data services can be based on standard interface or not
- Remote operations can be in the same country as data centre or not
- Local information can be shared from the ATSUs to the data centres are:
 - Local surveillance information
 - Local aeronautical information (runway in use, etc.)
 - Local sectorisation information

3.3.3.2 Benefits

In addition to the benefits identified for the implementation of a Virtual Centre within an ANSP (See 3.3.2.2), the table below provides a list of complementary benefits when widening the collaboration to cross-border operations.

Туре	Benefit
Business	 Contingency between ANSPs in case of failure of one Virtual Centre,
	 Decreased cost of ownership (sharing servers and applications in Virtual Centre)
	 Increased potential to outsource data production and processing on a performance basis across multiple ATSPs
Technical	Increased system harmonisation and easier system upgrades within the virtual centre.
Operational	 Load balancing between sites, from different countries possibly in order to handle capacity issues or to reduce weekend work at one ATSU location;
	 Improved flexibility for the ATFM functionality to balance demand across centres (potentially leading to lower traffic risk and therefore less accurate traffic forecasting required).
	 Potential reduction of environmental impact by allowing balancing demand and capacity and therefore to fly the most environmentally friendly route.

Table 3 - Benefits of Virtual Centres with cross-border operations

3.3.3.3 Impact

Such cross-border virtual centre impacts:

- · ATCOs and ATSEPs, organisation and training
- Day to day operations
- Synchronisation and alignment needs between ATSUs
- Global ATM architectures including voice communication systems, sensors local information sharing with cybersecurity concerns

3.3.3.4 Challenges

In addition to the challenges identified for the implementation of a Virtual Centre within an ANSP (See Section Challenges), the table below provides a list of challenges that need to be considered when widening the collaboration to cross-border operations.

Туре	Challenge
Political Regulatory	State sovereignty concern
	 The justification for such an organisational change is perceived as political and not enough operational
	\cdot The risk sharing and charging mechanism between States must be agreed
Business	ANSP reluctance to transform the business models
	Commercial self-determination
	 Complexity of service borders and scope definition Lack of standardisation of service interfaces in VC.
	Insurance and liabilities
Technical	Sharing of CNS infrastructure between countries
	Reinforced safety/cybersecurity on WAN for ATM data services can be costly
	 Difficulty in establishing standards to support the full range of potential implementations
Operational	Maintaining safety levels
	Interoperability between ADSPs and ATSUs (i.e. different CONOPS)
	Alignment of operational procedures of the ATCOs
Staff	 A common ATCO and ATSEP licensing and certification regime/scheme that enables to implement delegation use cases.
	Staff acceptance
	Different habits of controllers

Table 4 - Challenges of Virtual Centres with cross-border operations

3.3.3.5 Examples

3.3.3.5.1 MUAC and Slovenia

The project aimed to conduct a study, led by EUROCONTROL's Maastricht Upper Area Control Centre (MUAC) and Slovenia Control, to investigate the extent to which ATM data services can be provided by an ATM Data Service Provider's (ADSP) interoperable ATM system to one or more civil Air Traffic Service Units (ATSU). Kicked off in 2015, the first phase of the study was to develop and deploy a prototype which could support the provision of ATM data, in an operational ATM environment, from an ADSP to one or more civil ATSU. It concentrated on how an existing ANSP's information and communications infrastructure should be upgraded to receive data from an ADSP. Following the development of the prototype, shadow operations of live air traffic under the responsibility of Ljubljana Area Control Centre were successfully conducted in June 2016 at Slovenia Control, using the remote data provided by the operational ATM system at Maastricht.

The final objective was to collect all the information and expertise required to support further implementation by other European air navigation service providers, laying the foundations of SESAR's Virtual Centre concept.

The AdaaS Demonstrator used local radars, tracking and safety net services, but was fed by remote FDPS services from MUAC. In addition, the MUAC controller working positions and human-machine interface were deployed within Slovenia Control.

Phase 3 of the ADaaS Demonstrator was successfully completed with shadow operations in October 2017. Phase 3 provided essential data on how to deploy a state-of-the-art data centre from which an ADSP can deliver services to ATSUs with proper contingency and disaster recovery. The focus of the last shadow exercise was on seamless transition of ATM data services, which allowed switchovers of remote and local FDPS without any impact on operations. An important feature of this approach can be the utilisation of SWIM compliant data exchange protocols and open service-oriented architecture (SOA) as vital elements. Its aim is to provide ATSUs with an interface that allows its own CWP (or other systems that require ATM data as a service) to connect with a remotely located FDPS.

3.3.3.5.2 IAA/ISAVIA: improved connectivity to support oceanic operations

The ANSPs of Ireland, the Irish Aviation Authority (IAA) and Iceland, ISAVIA have implemented full unlimited virtual Joint Operations, which enables their Aeronautical Communications Centres to be fully interconnected.

The IAA and ISAVIA have commenced full unlimited "Virtual" operations, this enables the IAA and ISAVIA to become the world's first "Cross-Border" Aeronautical Communications Centre. The system is located at the IAA, North Atlantic Communications facility, Ballygirreen. ISAVIA with an identical system at its communication facility at Gufunes, Iceland, will enable both Voice Communication Systems to operate as one Virtual Centre. The system will be used to provide aeronautical communications services, using HF, VHF and SATVOICE operations, in the Shanwick and the Reykjavik Oceanic Control area (approx. 5.4 million square kilometres) under Joint Operations with ISAVIAs "Iceland Radio" and the IAA's "Shanwick Radio" (approx. 2.0 million square kilometres).

The concept of a virtual centre allows both centres to be operated either independently from each other in stand-alone mode or, when connected with each other, in joint-operation mode, which will give operational staff access to all resources and functionality of either Voice Communications Switch.

3.3.3.5.3 Finland and Estonia: dynamic cross-border virtual centre program

Estonian Air Navigation Services (EANS) and Fintraffic ANS, the main air navigation service providers in Estonia and Finland have a long record of excellent cooperation in the field of ATM because of their adjacent areas of responsibility and the need to coordinately manage the traffic flows to/from biggest airports under their responsibility – Helsinki-Vantaa and Tallinn. After implementation of cross-border Free-Route airspace in the region there was an opportunity and demand for further cross-border cooperation. In 2016, both companies shared interest to initiate more enhanced cross-border cooperation and the FINEST program was initiated.

FINEST aims to shape the future airspace via dynamic cross-border collaboration that enhances the efficiency, raises the capacity and makes the companies more competitive in the market.

The objective is to be achieved by:

- Organising cross-border, homogenous, dynamic, cost-efficient, more environmentally friendly and competitive Air Navigation Services by EANS and Fintraffic ANS for the benefit of airspace users;
- Designing the airspace to support most efficiently today's and future traffic flows;

- Developing and implementing technical environment (e.g. one FDP in the ATM system) supporting the dynamic cross-border services;
- Establishing the common rostering for EANS and ANS Finland ACC personnel;
- Ensuring continuous contingency in service provision;
- Harmonising and enhancing working methods and procedures within Tallinn FIR and Finland FIR to ensure further development of ATC capacity in accordance with EU/SES requirements.

The FINEST cross-border service area consists of Helsinki and Tallinn FIRs (EFIN and EETT) between FL095 until FL660.

To support the traffic flow, airspace will be re-organised and a new set of air blocks will be established. Sectors will be compiled from the specific air blocks to support the existing traffic flow. Within this area the ATC sectors are designed according to the traffic flows instead of national borders. The provision of ATC service within these sectors is dynamically transferrable between Tallinn and Helsinki ACCs.



Figure 4 – Futuristic example of the air blocks and their compilation for managing the traffic demand in morning, afternoon and evening traffic

3.3.3.5.3 Finland and Estonia: dynamic cross-border virtual centre program (continued)

Despite the economic situation, FINEST program is very important and will be continued as both companies see benefits to their customers after implementation. The aim is to implement the programme with the technical solutions, interfaces and operational harmonisation by April 2022. As both companies have been using the same ATM system as operational air traffic system for more than a decade, the upgrade to a unified solution is the cornerstone for this dynamic service provision. As the companies aim for efficiency in all areas of the cooperation, the environmental aspect has been taken seriously into account.

By the end of 2020, the airspace was defined, work with the operational harmonisation is ongoing and technical solutions for ATM and ATC to support the cross-border operation have been selected and implementation is ongoing.

Together with respective NSAs (Traficom and Lennuamet) several topics are being discussed:

- Licensing, rating and training (also the aspect of system-based rating);
- Liability, insurance and other legislative issues;
- Safety related information sharing and flow (occurrence reporting, investigations, safety assessments, etc); and,
- Change management including functional changes notification processes.

3.3.4 Implications on voice infrastucture

When mapping Figure 2 above to ATC voice systems, the following four main parts have to be considered:

- · Radio location, located anywhere in the countries,
- Infrastructure, to connect radio locations with towers/centres,
- Applications of the Voice Communication System (VCS) and legal recorders and others,
- CWPs at the controller's desk with the touch screen display and different audio accessories.



3.3.4 Implications on voice infrastucture (continued)

Moving towards virtualisation and breaking up the silos between the different ATM/ATC applications of course will also impact the voice systems. The next section examines how each part fits in the Virtualisation concept:

- The radio locations, which can be considered as a special kind of "sensors" (similar to a radar or weather stations). With the ED137 standard of the EUROCAE WG67 the radios provide a well-defined interface towards voice communication systems so that one or several VCSs can access and use the radio. But this ED137 interface is not only limited to VCSs but also can be accessed by legal recorders and other systems in order to collect data, e.g. voice quality monitoring system. Being seen as a kind of sensor, the radios and radio locations are part of the ADSP infrastructure. A similar approach also applies to radios used for data link services, such as CPDLC. While these radios can also be handled as a kind of sensor, the main difference is the interface to the ground infrastructure, which is not standardised as is the case with voice.
- The transport infrastructure, which is IP based and needed to connect the different locations. Here the same engineered IP infrastructure as for all other ATM data services, e.g. data link services, will be used, providing highly available, reliable and secure communication over LAN and WAN.
- The applications of the VCS, legal recorders and others, which are needed to provide some dedicated services to the ATCOs or system administrators. While these applications run in a virtual environment in a data centre, sharing the same hardware with other applications, the question is, "Are these VCS applications part of the ADSP or ATSU?" In case the voice applications run in a data centre of the ATSUs, the interfaces to the radios belonging to the ADSPs are well defined with the ED137 standard. This interoperability is well-proven for over a decade now. More interesting will be the situation, in case the voice applications run in data centres belonging to the ADSPs, as the

interface between VCS applications and CWPs is not standardised. In a single vendor environment, this is no problem, but in a multivendor environment, this is a challenge, which needs to be solved. Via open APIs the service-oriented and modular VCS and recording applications can also be integrated with other ATM applications, e.g. for role assignment/selection or configuration exchanges.

 The CWPs at the controllers' desks. While the graphical user interfaces for selecting radio/ telephony resources and certain functions might be integrated into a common integrated CWP with all other relevant ATM applications (incl. data link services like CPDLC), the connectors for the voice audio accessories (several headsets, speakers...) in most cases still will be provided as dedicated hardware to the ATCO.



3.3.4 Implications on voice infrastucture (continued)

Figures 5 and 6 visualise the two options mentioned in point 3 above. From today's perspective, we see both options in operation. One VCS for two ATSUs is seen mainly within a single ANSP, where one VCS supports several centres. Each ATSU having its own VCS represents similar deployments with Virtual Centres cross border involving two ANSPs (e.g. IAA/ISAVIA project or Finland/Estonia project).



Figure 5 – Data centres and Virtual Centres option 1



Figure 6 – Data centres and Virtual Centres option 2

3.3.4 Implications on voice infrastucture (continued)

Like for the other ATM applications, similar challenges are also applicable for voice systems:

- Standardised synchronisation mechanisms between voice applications of different vendors installed with different ADSPs/ATSUs:
 - Configuration sharing, e.g. air-ground and ground-ground resources, roles
 - · Detection of availability of the services
 - Switch over in case of failures
- Standardised APIs into the consoles
- Standardised APIs to other ATM applications for information and configuration sharing, e.g. roles



3.4 Lessons learnt

From all the examples above related to virtualisation of ATM service provision, the lessons learnt can be summarised as follows:

- A wider "virtual centre" construction is no longer a technological issue. All the technology is at hand and can be put in place. Adoption of a standard is opportune, especially for securing the infrastructure across organisational borders. The infrastructure can improve resilience through redundant WAN connections.
- All relevant ATM, as well as ATC applications, have proven to be suitable to support virtualisation in one way or another.
- It has been demonstrated that adoption of a virtual centre paves the way toward a wider area control centre which triggers the need for harmonising of ATCO licensing with appropriate training and ATC support tools.
- There is a need to involve the professional staff to share the operational objectives and the associated benefits in terms of safety enhancements and quality of service improvements. It is important to look into the social impact, including Personnel licensing.
- Used in the right way, the virtual centre could resolve some staffing issues and even gain ATCOs acceptability and satisfaction, as less weekend work or night shifts are needed.
- There is also a political perspective in the implementation of remote services which needs to be accompanied and explained, for example, by the assurance of the maintenance of the same level of service or even the increase of service.

Conclusions and Recommendations

As this examination of the current state of the virtualisation concept and related technologies has demonstrated, virtualisation is not a theoretical concept anymore. It is a reality which started to make its way to the ANSPs, in one form or another. The most prominent examples are remote/digital towers. With quite a number of remote/digital tower projects realised and operational it is safe to say, that the technology is in place and has a proven track record in order to realise remote/digital towers successfully. While virtualisation of area control centres is not yet as advanced the technology for virtual centres is in place and ready to go with some virtual centre deployments already operational or shortly to be in place, both national and cross border.

Virtualisation leads to a better balance of air traffic controller workloads and more efficient use of the airspace. Further increased safety, decreased delays and traffic congestions as well as higher flexibility in handling air traffic can be expected.

Benefits will include operational efficiency and flexibility with an associated cost optimisation. These benefits will result in the improvement of Sector Load Balancing and the use of different technical architectures for ADSP implementation. An improved flexible use of ADSP Services would also allow operations in case of contingency and increase the resilience of ATM service provision.

In light of the definition of virtualisation given within this paper, where services are decoupled from technology, where ADSPs can be independent organisations from ATSUs, it has to be understood that this is as much an organisational issue as it is a technology issue.

The ANSPs as of today could consider managing the organisational change to facilitate the adoption of a SOA with a clear assignment of roles between the ATM data service provision and the ATS units. Considering the cybersecurity and safety aspects, ANSP shall expect impacts from virtual centres on procurement, engineering, operational and training activities. Beyond the technological changes, Virtualisation can change the ANSP organizational aspects in significant ways. Virtualisation to its largest extent decouples services from technology, i.e. innovative services supported by the same technology and maintaining the same services while improving the technology.

As a possible evolution, this could lead even to the establishment of two independent companies, with a possible competition with other ADSPs and ATSUs. It must be recognised that this decision is likely to be taken at a political State level (as being discussed in Europe with the SES2+ recast (2021)). In case of ADSP provided by another ANSP, the certification and liability topic need to be carefully analysed.

The development of the standards needs to take into consideration the interoperability aspects ensuring the safe and secure exchange of information but open enough to facilitate the digitalisation of the operational processes linked to different airspaces to be managed.

Moreover, virtual centres will facilitate the rationalisation (through centralisation) of equipment (servers) and thus the electrical consumption of the ATM activities, targeting a positive impact on the environment.

From an airspace users' perspective, virtual centres and the common data layer will enable seamless ATS delegation and harmonised operational procedures and as a consequence, improvements in trajectories and flows are likely that will aid in reduction of CO_2 emissions.

The implementation will require a step-approach to address the various challenges such as political, regulatory, business, technical and operational issues. While it involves multiple stakeholders and significant change, the perceived benefits may enable a more resilient, efficient and scalable ATM solution for the future.

Appendix Acronyms and Abbreviations

Acronym	
ACC	Area Control Centre
ADS-B	Automatic Dependent Surveillance – Broadcast
ADSP	ATM Data Service Provider
AIS	Aeronautical Information Services
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
APP	Approach
ΑΤCΟ	Air Traffic Controller
АТМ	Air Traffic Management
ATSEP	Air Traffic Safety Electronics Personnel
ATSP	Air Traffic Service Provider
ATSU	Air Traffic Service Unit
CANSO	Civil Air Navigation Services Organisation
CONOPS	Concept of Operations
COTS	Commercial Off The Shelves
CPDLC	Controller Pilot Data Link Communication
CWP	Controller Working Position
FDPS	Flight Data Processing System
ΙCAO	International Civil Aviation Organization
LAN/WAN	Local Area Network/Wide Area Network
NSA	National Supervisory Authority
SES	Single European Sky
SESAR	Single European Sky ATM Research
SLA	Service Local Agreement
SOA	Service-Oriented Architecture
SWIM	System Wide Information Management
ТМА	Terminal manoeuvring area
TWR	Tower
VCS	Voice Communication System



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